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CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

1822[60]

JOURNAL DU CONSEIL

VOL. XX · NO. 1

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

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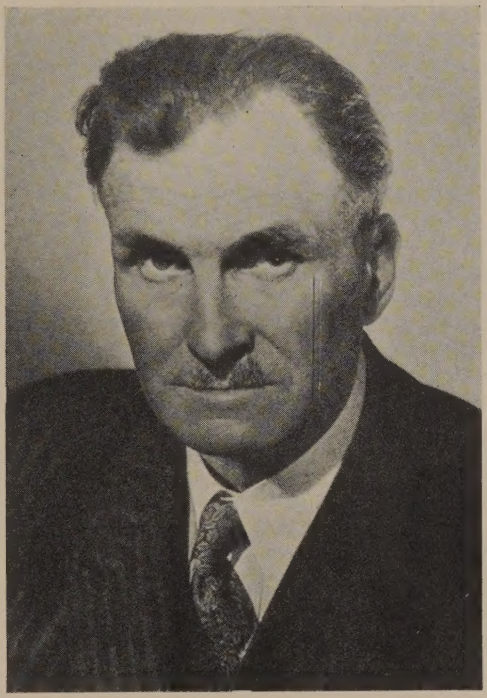
EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

JUILLET 1954

IMPRIMERIE A/S L. IHRICH . COPENHAGUE



Jean le Gall.

1894—1954.

JEAN LE GALL nous a quittés le 6 Février 1954, terrassé par une longue maladie contre laquelle il a lutté courageusement, travaillant jusqu'au bout. Le Conseil Permanent International pour l'Exploration de la Mer perd en lui son premier Vice-Président; l'Institut Scientifique et Technique des Pêches Maritimes, son Directeur.

Jean le Gall est né à Brest le 11 Mai 1894; il commence ses études à la Faculté des Sciences de Rennes en 1912. Il est mobilisé en 1914 et blessé au cours des premiers mois de la guerre; son attitude courageuse au front lui vaut l'attribution de la Croix de Guerre. Il rejoint en 1917 la Faculté de Rennes où, déjà licencié ès-sciences, il passe le diplôme de Chimiste

d'Université. Titulaire d'une bourse d'études des Universités américaines, il effectue en 1919 un stage à Urbana dans l'Etat d'Illinois où il obtient le diplôme de "graduate". Il est alors nommé professeur à Morlaix, puis à Brest, Vitré, Vendôme; et réussit l'agrégation en 1924.

Cette même année commence sa longue carrière à l'Institut Scientifique et Technique des Pêches Maritimes où il est appelé comme chef de laboratoire par le Directeur J o u b i n. C'est à Boulogne qu'il gagne l'estime des milieux maritimes français et étrangers, par ses travaux sur la pêche et sur la biologie des principales espèces comestibles. A partir de 1925, année où il publie une étude sur le hareng et sa pêche, son activité scientifique ne connaîtra plus de repos.

La sardine, le hareng du sud de la Mer du Nord et de la Manche Orientale, le maquereau, le germon, le thon rouge, le merlu, la coquille St-Jacques, les crustacés font l'objet de sa part de travaux scientifiques et d'intérêt pratique très appréciés. Il reçoit en 1935 le prix G e o r g e s K o h n de l'Institut Océanographique. Il rédige des notes sur la pêche en Islande, en Norvège, en Guinée, et en Côte d'Ivoire, sur les engins et les techniques de la pêche, sur la réglementation, les ennemis et les parasites des mollusques comestibles, la détection des bancs de poissons. Il s'intéresse aussi au traitement du poisson à bord et à terre, au fumage, aux procédés de conservation des produits de la mer par le salage et le froid. Ses travaux ont paru dans des revues techniques françaises et étrangères, dans les publications de l'Institut Scientifique et Technique des Pêches Maritimes et du Conseil International pour l'Exploration de la Mer.

Mais il n'oublie pas sa formation initiale et sa haute compétence lui vaut d'être choisi pour inculquer aux futurs spécialistes les notions fondamentales sur l'océanographique, la pêche, les produits des industries de transformation.

C'est un savant de laboratoire et un spécialiste éclairé mais aussi un navigateur infatigable. Embarquant sur les bateaux de pêche et les navires garde-pêches de la Marine il étudie principalement les conditions hydrologiques en Manche, en Mer Celtique, et dans le Golfe de Gascogne. Il participe dès 1933 aux campagnes du navire océanographique "Président Théodore Tissier", les organisant avec soin depuis 1946.

Il est chargé de nombreuses missions d'études à l'étranger, en Norvège (1925), en Islande (1930), en Angleterre, en Espagne, au Portugal, et dans d'autres pays. En 1929 il est désigné comme expert au Conseil Permanent International pour l'Exploration de la Mer; en 1945 il est nommé Président du

Comité du Plateau Continental Atlantique et il exerce depuis 1949 les hautes fonctions de Vice-Président du Conseil International. Ses collègues étrangers lui confient en 1952 les charges de Secrétaire Général de la Commission Internationale pour l'Exploration de la Mer Méditerrannée, et de Président du Conseil Général des Pêches pour la Méditerranée.

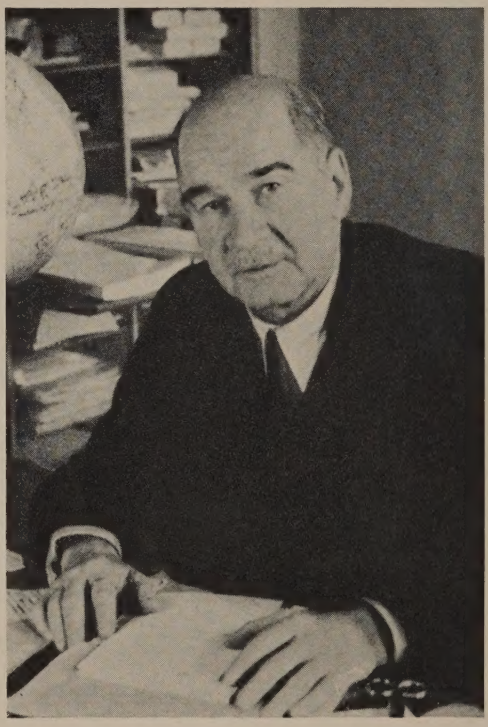
En plus de ces commissions internationales, de nombreux comités nationaux, scientifiques aussi bien que professionnels, font appel à sa compétence. Entre-temps en effet il a pris la direction de l'Institut Scientifique et Technique des Pêches Maritimes (1945).

Le monde maritime et le personnel de l'Institut Scientifique et Technique des Pêches Maritimes garderont de Jean le Gall un souvenir ému, rempli d'admiration pour son activité infatigable et de gratitude pour ses conseils désintéressés et la simplicité de son accueil.

Notre pays, pour honorer ses services, lui avait décerné les grades d'Officier de la Légion d'Honneur, de Commandeur du Mérite Maritime, et d'Officier de l'Instruction Publique. Les Gouvernements étrangers avaient reconnu également sa haute valeur: il était en effet Officier de l'Ordre de la Couronne Belge et Chevalier de l'Ordre Royal de Danebrog.

En Jean le Gall, nous perdons un éminent chercheur et un marin éprouvé, un conseiller expérimenté et un grand ami.

P. Desbrosses.



Risto Jurva.

1888—1953.

RISTO JURVA passed suddenly away on 8. December 1953, aged 65.

Jurva was a native of an Ostrobothnian family and grew up in the Bothnian coastal town of Wasa. Entering the University of Helsinki in 1906, he began studying physics and mathematics, with the intention of taking up a scientific career. Then in 1908 he became an assistant at the Meteorological Institute. During his four years there his main work was helping in the production of weather maps and the preparation

of daily weather forecasts. His hobby was the study of night frosts and thunderstorms in Finland.

This appointment and the onset of World War I (despite the fact that Finland was not directly engaged in it) interrupted his University studies, and he did not graduate until 1918. In 1919 he was appointed an assistant at the Institute of Marine Research in Finland. In 1938 he presented the dissertation for his doctorate. In 1940 he became head of the Institute's Ice Department, and from 1947 to the time of his death he was Director of the Institute.

These bald details conceal a rich and active life, for the main part devoted to science. Jurva did not marry until 1949. In the Institute of Marine Research Jurva's work was from the very beginning centred on the Ice Department. His skill at drawing and his disposition to seize upon the visual angle of attack on a problem formed a good foundation for his ice researches. As an ice investigator he has done work of lasting value. He had, too, the satisfaction of seeing his scientific results put to considerable practical use. At the meetings of the International Council he gave several lectures about his ice researches, which were well received. For Finland this matter is of course a very important part of marine research, though for most of the participating countries it is only of secondary interest.

Another of Jurva's interests was seismology. He was connected with the seismic station at the University of Helsinki from its foundation in 1924 until 1945, and was thereafter its Superintendent until his death.

On account of his knowledge of oceanography, meteorology, and seismology Jurva was nominated Academic Docent at Helsinki University in 1938. In this capacity he always showed great personal interest in his students.

Jurva also found time to spare for the scientific societies in Helsinki. His most demanding and laborious post in this regard was his position as secretary and editor of the Geographical Society of Finland.

Jurva was always a helpful and attentive man, but he was nevertheless able to assert, in a polite and respectful way, his own opinion, and, if necessary, hold his position firmly.

His wife and daughters have lost a good husband and father. They and his many friends — among whom I am proud to be counted — deeply mourn his loss.

Gunnar Granqvist.

Corrigendum.

Faune Ichthyologique de l'Atlantique Nord.

Our attention has been drawn to an error in the sheets relating to **Gadus callarias** (2) and **Gadus merlangus** in Folder No. 18 of the series *Faune Ichthyologique de l'Atlantique Nord*. The illustration shown for the post-larval stage of *G. merlangus* at 32 mm. is in fact that of *G. callarias* at 46 mm.; that shown for *G. callarias* at 46 mm. is *G. merlangus* at 32 mm. The two illustrations should be exchanged without alteration of the lettering.

The series having terminated, it is not possible to publish a correction of this error in the series itself.

An Apparatus for Determining the Salinity of Sea Water.

By

R. A. Cox,

National Institute of Oceanography, Wormley.

THE Spilhaus Sea Sampler (1) has made intensive study of the detailed structure of the surface layers of the ocean a reasonable proposition. When the instrument is in use, however, so many samples can be taken in a given time that it is hardly possible to make the corresponding determinations of salinity by conventional methods. The apparatus to be described was developed as one of several possible methods which seemed likely to give a more rapid determination.

The principle of the apparatus is the measurement of the density of a water sample by means of a total-immersion hydrometer of variable density. A number of designs for apparatus for direct density determinations on sea water has been published (2—12) but all of them suffer from serious disadvantages in practice. In general the methods are either of insufficient accuracy or too slow in operation. The apparatus described by Verney Stott (6), for example, uses a float of accurately adjusted density immersed in the water sample. The sample is warmed until its density becomes equal to that of the float, the temperature at which this occurs being a measure of the salinity of the water. Although admirably simple in theory, this apparatus suffers from two serious faults. Firstly the time taken for a determination is too long, as the rate at which the temperature can be varied is slow. Secondly, most sea water is approximately saturated with dissolved nitrogen and often with oxygen. On warming, bubbles of gas, often too small to be visible, form on the float and may cause serious errors.

In considering ways in which this latter difficulty might be overcome one suggestion was to maintain a small positive pressure of air above the water in the apparatus, hence avoiding the tendency for gas bubbles to separate. The suggestion was then made that if the float were to be made slightly compressible, this air pressure could be used to vary its

specific gravity and hence avoid the slow temperature changes necessary in the Verney Stott apparatus, as pressure changes can be made much more simply and rapidly. This is the principle on which the new apparatus depends. It resembles in many ways the traditional "Cartesian Diver", except that the float is completely sealed and does not depend for its action on the compressibility of the contained air.

Design of Apparatus.

The general design of the apparatus is shown in diagrammatic form in Figures 1 and 2. The float is made by blowing a thin-walled bulb about 2 cm. in diameter on the end of a length of 7 mm.-bore tubing. One or more faces of the bulb are then gently heated and allowed to collapse to form a thin fairly flat surface. After annealing, the tube is drawn down about 2 cm. from the bulb and cut off. A small amount of mercury is introduced until the bulb is only slightly lighter than sea water, the drawn-down stem is sealed, and final adjustment made to the float by adding or removing small quantities of glass until the float is neutrally buoyant in a sea-water sample a little less saline than the desired working range of the instrument. The working range of a float will depend on the dimensions of the flat surfaces, the volume of the float, and the available range of pressure variation. The results described in this paper were obtained with a float covering the range of 33 $^0/_{00}$ to 36·5 $^0/_{00}$ in salinity for a pressure change of about one atmosphere. This float had two flat surfaces each approximately 17 mm. in diameter and 0·25 mm. in thickness, and was proved capable of withstanding pressure differences of one atmosphere by evacuating with a pump before counterweighting and sealing. The float is contained in a pyrex-glass chamber surrounded by an unsilvered vacuum jacket to minimize temperature variations. Behind the chamber is a grid of fine horizontal lines illuminated by a low-voltage lamp to facilitate observation of slow movements of the float, and mounted in front a lens 10 cm. in diameter and 15 cm. focal length to amplify the movements. The sample of water under test is run in through the funnel and the tap A, and after a determination, run out through the tap B. The volume of water required for a determination is about 70 ml., without allowing for rinsing. The volume of the previous sample left in the chamber and tubes after draining is about 0·4 ml. Rinsing is hence quite unnecessary if successive samples differ in salinity by less than 0·2 $^0/_{00}$, as any error introduced will be inappreciable. If variations are greater than this a preliminary rinse is necessary for high accuracy. Apart from this slight contamination from the previous sample the water used is unchanged and could be used afterwards for chemical investigations if convenient. The two taps A and B are spring loaded to withstand the pressure inside the apparatus. A thermometer calibrated to 0·1°C. is held in the top of the float chamber by a rubber bung, by removal of which access may be obtained to the float for cleaning or other purposes. When the chamber is filled the bulb of the thermometer serves to hold the float

below the water surface. Any tendency of the float to jam between the bulb and walls can be prevented by a small disk of platinum foil fixed to the bulb. A side arm above the vacuum jacket connects the float chamber to the pressure system, and this is provided with a splash trap E to avoid any danger of salt water reaching the manometers, should the chamber be overfilled. The pressure system (see Figure 2) consists of a tank filled by a hand pump and connected to a mercury manometer. A fine needle-valve C admits air from this tank to the float chamber, to which is connected a second manometer. A second needle-valve D allows the air from the chamber to escape to the atmosphere. After a sample has been run into the chamber, air is admitted through C until the float starts to sink. The pressure is then adjusted by suitable use of C and D until the float remains stationary near a convenient reference line. The pressure in the manometer is then a measure of the density of the water at the time of the measurement.

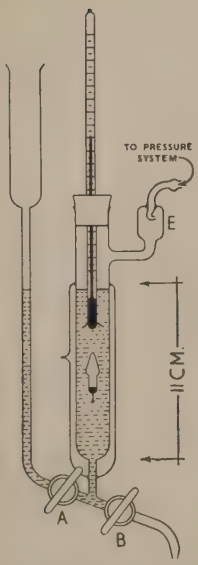


Figure 1.
Float chamber and float.

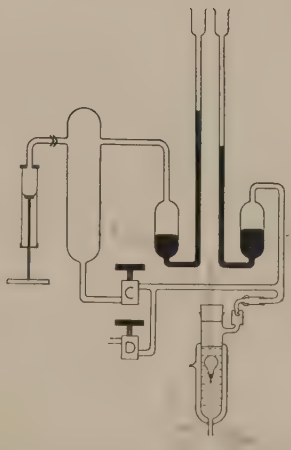


Figure 2. Diagram of pressure system (not to scale).

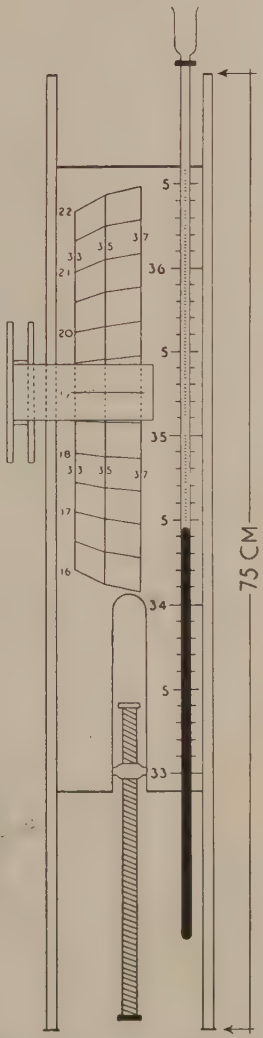


Figure 3. Arrangement of sliding scale.

From this figure and the temperature of the sample it would of course be possible to compute the salinity and the density at any other temperature. For convenience and for comparison with other methods the instrument is provided with a scale behind the manometer reading direct in salinity. Since the instrument is not maintained at a constant temperature, means must be provided to compensate for temperature variations. This is done by mounting the scale in vertical slides so that it can be raised and lowered by a screw device. Mounted beside the salinity scale is a second scale calibrated in temperature (see Figure 3). The temperature of the sample is read immediately the float is stationary and the sliding scale is adjusted until the reference line indicates the same temperature. The multiple temperature scale shown in Figure 3 will be discussed later. This adjustment of the slide corrects for the variation in temperature between samples.

Before each series of measurements the instrument is calibrated against sea water of known salinity. The zero point of the instrument varies from day to day with barometric pressure changes, and also very slightly due to accumulation of grease on the float, and should therefore be checked at least every few hours. Variations in the zero are allowed for by adjusting the reference line relative to the instrument panel until, when the slide is set to the temperature of the standard water sample, the manometer reads the correct salinity.

For the initial calibration of a new float a linear scale such as a boxwood metre rule is fixed behind the manometer. A series of standard sea waters of various salinities (and as nearly as possible at the same temperature) is then used to fix a number of points corresponding to these salinities. The salinity scale can then be drawn up by interpolation. In general it will be found to be a very close approximation to a linear scale. The calibration of a float is shown in Table 1.

Table 1.

Salinity of test water	Pressure in mm.	Vertical interval for 1 ‰ salinity
33·00	31·5	
34·00	208·7	177·2
35·00	381·2	172·5
36·00	549·9	168·7

It is now possible to compute the temperature scale from these figures and the hydrological tables. If we call the pressure change corresponding to a salinity change of 1 ‰ one unit, then the pressure change corresponding to 1°C. is given in Table 2.

Table 2.

Pressure change equivalent to 1 ‰ salinity is 1·000

Temp. change, °C.	16—17	17—18	18—19	19—20	20—21	21—22	22—23
Pressure change	0·318	0·331	0·345	0·359	0·373	0·386	0·400

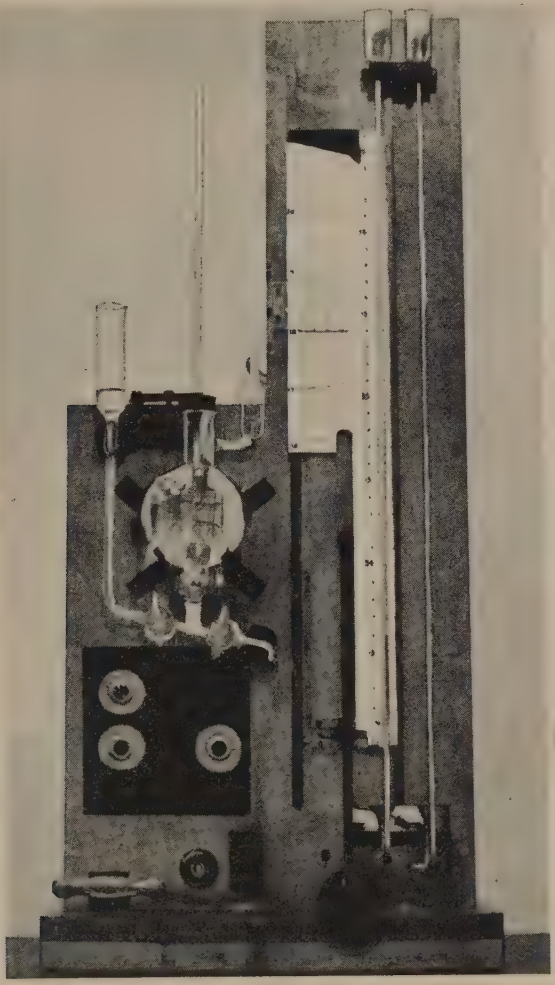


Figure 4. General view of instrument.

It will thus be seen that the temperature compensation scale is not a linear one, due to the expansion characteristics of water. However, the density change corresponding to a change of 1 ‰ salinity is a constant within experimental error over the range of ocean waters and at any temperature above 15°C. Given a float with a linear response to pressure, the salinity scale is hence also linear over this range. In this case the temperature scale can be computed from Table 2 and will be

accurate at any salinity. If, however, the float response is not linear, then the temperature correction will depend on which part of the scale is in use. It is possible to compute a series of temperature scales to compensate for this error, each accurate at a particular salinity, and such a series is shown in Figure 3. In analysing a series of samples over a narrow salinity range, but differing in temperature, it is then possible to use the appropriate temperature scale. When analysing samples over a wide range of salinity, however, it is necessary to use a temperature scale corresponding to the mean salinity, and in these circumstances should the temperatures of the samples vary considerably, errors will be introduced for which the machine cannot compensate, and the accuracy will suffer. Fortunately such conditions are rare as it is seldom necessary or convenient to analyse samples within an hour or two of their being taken. Samples in similar bottles stored together in a room at a reasonably equable temperature rarely differ in temperature by more than a few tenths of a degree, in which case the errors can be disregarded. It should be emphasized that the more linear the float, the less these errors become, and every effort should be made to make a float with the desirable characteristics.

The only difficulties which arise in the use of the apparatus in the laboratory are a tendency for small air bubbles to stick to the float during filling, and a stratification effect in the water due to running in a sample considerably different in temperature from the walls of the chamber. Both are easily remedied by opening tap A and pushing the water back into the filling funnel by admitting a little air through valve

Table 3.

Water A.	Salinity by titration	Salinity by new apparatus	Water C.	Salinity by titration	Salinity by new apparatus
	33·307	33·302		35·302	35·308
	33·303	33·308		35·302	35·312
	33·305	33·300		35·310	35·307
	33·300	33·305		35·308	35·304
	33·300	33·302		35·305	35·303
	33·305	33·310		35·310	35·304
mean	33·303	33·304	mean	35·306	35·306
mean deviation	0·002	0·003	mean deviation	0·003	0·003
Water B.			**Water D.**		
	34·291	34·299		36·305	36·300
	34·301	34·301		36·298	36·298
	34·297	34·300		36·305	36·302
	34·304	34·297		36·305	36·305
	34·299	34·304		36·303	36·300
	34·299	34·303		36·300	36·302
mean	34·299	34·301	mean	36·303	36·301
mean deviation	0·003	0·002	mean deviation	0·002	0·002

C. When the water level has reached the lower end of the chamber, C is closed and D opened, and the water runs back without bubbles and at a uniform temperature. Cleaning is effected by running in nitric acid through the funnel and allowing to stand overnight, followed by thorough rinsing and, if necessary, re-greasing the taps.

Results.

Table 3 shows the results of a series of determinations undertaken to compare the precision of the apparatus under good conditions with those obtained by titration. The titration figures were obtained with a salinity burette and pipette manufactured by Richter & Wiese of Berlin and carefully re-calibrated with silver nitrate solution. The indicator used was a solution containing 1 % soluble starch and 0·05 % fluorescein sodium salt, 1 ml. being used for each titration. The author adopted this indicator initially, as defective colour vision prevented accurate judgement of the chromate end-point, but even with observers with normal colour vision it seems to give a slight increase in precision.

It will be seen from the table that there is little to choose between the two methods in absolute precision, and with care both are capable of results well within the required accuracy. Table 4 gives results from an artificial series of samples made by mixing carefully measured quantities of waters of accurately determined salinity.

Table 4.

True salinity by calculation	Observed salinity	Difference
33·303	33·304	+0·001
33·503	33·496	—0·007
33·704	33·705	+0·001
33·904	33·905	+0·001
34·105	34·104	—0·001
34·302	34·302	nil
34·512	34·510	—0·002
34·719	34·721	+0·002
34·926	34·926	nil
35·133	35·137	+0·004
35·340	35·341	+0·001
35·533	35·531	—0·002
35·725	35·723	—0·002
35·918	35·918	nil
36·110	36·109	—0·001
36·303	36·307	+0·004

mean difference: less than 0·002 ‰
maximum error: 0·007 ‰

Finally Table 5 gives two sets of analyses, in one case by the author as a test of speed and in the other by two completely inexperienced workers who had never previously used the apparatus. The workers had no previous knowledge of the expected salinity of the samples.

Table 5.

Series A — widely spaced samples

True salinity	Experienced worker	Error	Inexperienced worker	Error
33·52	33·52	nil	33·49	—0·03
33·72	33·72	nil	33·69	—0·03
33·92	33·93	+0·01	33·94	+0·02
34·12	34·13	+0·01	34·11	—0·01
34·32	34·32	nil	34·32	nil
34·66	34·69	+0·03	34·66	nil
35·01	35·00	—0·01	35·01	nil
35·35	35·35	nil	35·36	+0·01
35·69	35·69	nil	35·69	nil
36·00	36·01	+0·01	36·02	+0·02
36·31	36·33	+0·02	36·38	+0·07

Series B — designed to resemble samples from a typical deep-sea station.

True salinity	Experienced worker	Error	Inexperienced worker	Error
34·33	34·34	+0·01	34·33	nil
34·30	34·32	+0·02	34·29	—0·01
34·33	34·33	nil	34·31	—0·02
34·30	34·32	+0·02	34·28	—0·02
34·27	34·27	nil	34·26	—0·01
34·25	34·24	—0·01	34·24	—0·01
34·21	34·22	+0·01	34·20	—0·01
34·25	34·24	—0·01	34·25	nil
34·13	34·11	—0·02	34·15	+0·02
33·92	33·93	+0·01	33·93	+0·01
33·72	33·72	nil	33·72	nil
33·68	33·68	nil	33·69	+0·01
33·70	33·69	—0·01	33·73	+0·03
33·68	33·66	—0·02	33·70	+0·02
33·70	33·69	—0·01	33·72	+0·02

It will be seen that with only one exception the results of even the inexperienced worker were within ±0·03 of the correct figure, a much higher accuracy than an inexperienced worker would attain by titration. In this series the average time taken by the author over each determination was 3 min. 5 seconds. This compares very favourably with the time required for titration to a comparable accuracy, which has been estimated for a number of workers to vary between five and ten minutes per determination, plus the time for correcting and calculating the figures from K n u d s e n' s tables.

Tests on Board Ship.

The apparatus was tried experimentally on board R.R.S. "Discovery II" on routine station work. It was found that in the open sea, even with the ship hove to on station, there was always too much vertical movement to make the instrument practicable. This movement caused

a pumping motion in the manometer, which made anything but very approximate readings impossible. A modified instrument which it is hoped will overcome this failing is under construction and will be tested at sea during 1954.

Conclusion.

1) A new instrument has been designed for determination of salinity by density measurement.
2) The precision of the instrument is comparable with that of titration.
3) The apparatus is approximately twice as fast as the normal titration procedure. This is a considerable advance, but is still not as rapid as is desirable for use with the Spilhaus Sampler.
4) The instrument can be used successfully by untrained personnel, and very little practice is needed to obtain results as good as the average results by titration.
5) The instrument is always ready for use and needs no chemicals or other materials except a supply of water of known salinity. It is reasonably portable and could be used in any workroom without needing water, electricity, or other services, but for accurate work it needs a reasonably uniform temperature.
6) In its present form the instrument cannot be used in a ship at sea if it is subjected to appreciable vertical accellerations. A modified design is under construction which it is hoped will be usable at sea in reasonable weather.

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The Bactericidal Effects of Sunlight in Relation to "Light" and "Dark" Bottle Photosynthesis Experiments.[1])

By

R. F. Vaccaro and **J. H. Ryther,**
Woods Hole Oceanographic Institution.

THE Gran oxygen method for measuring photosynthesis (Gaarder and Gran, 1927) presupposes that respiration by native plankton populations is equal in both "light" (transparent) and "dark" (opaque) bottles. Steemann Nielsen (1952) has proposed that this precept is violated when observations are extended beyond 24 hours. He emphasizes that prolonged exposure to ultraviolet and visible solar radiations inhibits bacterial development in the light bottles. As a result the greater amount of respiration resulting from the dark condition is not a true indication of respiration in the light bottles. Estimates of photosynthesis on this basis would therefore be excessively high. Ryther and Vaccaro (1954) on the other hand obtained photosynthesis values from long-term oxygen experiments equal to or lower than those derived from experiments of 24 hours or less. The status of future measurements of photosynthesis by the oxygen method is dependent upon a resolution of these inconsistencies.

In support of his argument, Steemann Nielsen has cited the observations by Meader (1926), who demonstrated a measurable bactericidal effect from solar wave-lengths transmitted through a glass plate (8 mm. thick). However, Mashimo (1919) noted the effectiveness of a glass plate (10 mm. thick) in removing the bactericidal wavelengths from sunlight. In neither of these two cases were the experimental conditions sufficiently related to the Gran oxygen technique to permit a realistic assessment of the problem.

The validity of Steemann Nielsen's contention is dependent upon positive demonstration that under the conditions of the experiment

[1]) Contribution No. 683 from the Woods Hole Oceanographic Institution.

the effects of sunlight induce a measurable restriction on bacterial growth and respiration. As a result we have undertaken an investigation of the bactericidal effects of sunlight in light and dark bottle photosynthesis experiments. Our observations have failed to uphold Steemann Nielsen's viewpoint, in that no measurable bactericidal activity has been noted.

In general the literature supports three different opinions as to the effects of light energy on bacterial populations. Without notable exception all are in agreement that bacteria are sensitive to middle ultraviolet radiations (200—300 mμ). However, Ward (1892) and Mackie and Van der Lingen (1926) also attribute inhibitory activity to visible and infrared rays. A second viewpoint is upheld by Bayne-Jones and Van der Lingen (1923) and Coblentz (1924), who consider bacteria to be mildly sensitive to near ultraviolet radiations (300—390 mμ). Finally, what is probably the predominant opinion is typified by Bachem and Dushkin (1935), who restrict significant bactericidal activity to wave-lengths shorter than 300 mμ with a maximum activity corresponding to 265 mμ.

Besides wave-length, intensity and duration of exposure must be considered. The Bunsen-Roscoe law as supported by Bachem predicts that for unchanging cell sensitivity, equal products of intensity and time induce comparable bactericidal activity. Bachem holds that the lethal effects of ultraviolet radiations follow this mode of behaviour.

Ultraviolet solar radiation as modified by the earth's atmosphere is a case in point. At sea level the lower limit of the solar spectrum is in the vicinity of 290 mμ. As compared with middle ultraviolet these wave-lengths are not especially lethal for bacteria. However, the great intensity of solar radiation makes it an extremely effective bactericidal agent under ideal atmospheric and experimental conditions.

According to Luckiesh (1922) ordinary glass is opaque beyond the near region and generally opaque to energy wave-lengths shorter than 340 mμ. Steemann Nielsen is not unaware that glass possesses selective absorption characteristics for ultraviolet radiant energy but, as stated above, his interpretation is based on the Meader observation. In contrast to Meader's glass plate, the standard dissolved-oxygen bottle of the type commonly used in light and dark bottle experiments has an average wall-thickness of approximately 2·5 mm. We have studied the absorption spectrum for this glass using a constant source of ultraviolet radiations from a hydrogen lamp in a Beckman Model DU Quartz Spectrophotometer.

Figure 1 presents the percentage transmission as measured for wave-lengths between 280 and 350 mμ. At 350 mμ a little more than 50 % transmission was measured. Below 350 mμ the percentage removal increased rapidly until the glass proved opaque to more than 99 % of the incident intensity for wave-lengths shorter than 305 mμ. These results confirm those of Luckiesh in that all middle ultraviolet and more than 50 % of the near-ultraviolet wave-lengths were absorbed.

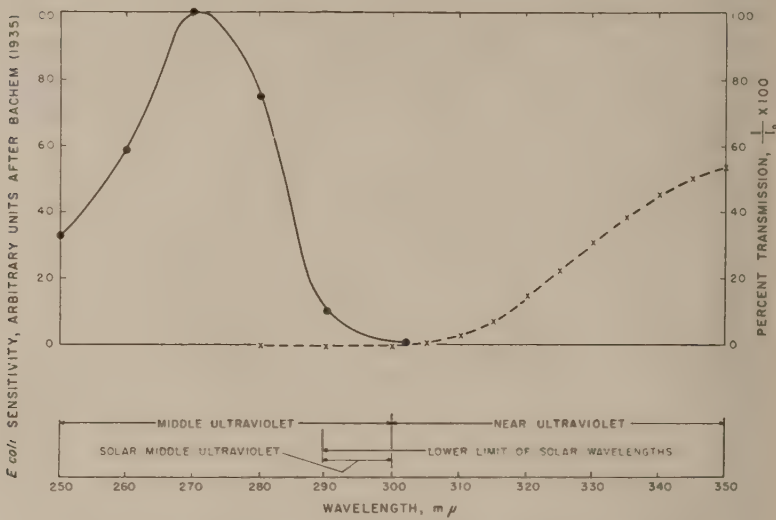

Figure 1. The spectral transmission through 2·5 mm. of glass (crossed) and the sensitivity of *Escherichia coli* (closed circles) for radiation 250—350 mμ.

For comparison the transmission-wave-length curve is related to the spectral sensitivity for *Escherichia coli* as determined by B a c h e m. The maximum *E. coli* sensitivity occurred at 270 mμ with only slight relative activity above 290 mμ and within the range of transmitted ultraviolet radiations.

C o b l e n t z (1949) has defined the range of biologically effective solar radiation as extending from 290—315 mμ. The mean coefficient of absorption (α) for this range is represented by the relation

$$I = I_0 10^{-\alpha x},$$

where I_0 is the initial light-intensity and I the intensity through distance x. From Figure 1 the mean coefficient of absorption by the glass oxygen-bottle for wave-lengths 290—315 mμ is 7·4 per cm. or 1·85 per 0·25 cm., the average wall-thickness of the oxygen bottle.

The mean coefficient of sea water for wave-lengths 280—313 mμ as obtained from H u l b u r t (1928) is 0·010 per cm. of depth. Under typical conditions light and dark photosynthesis bottles are immersed under 10 cm. of sea water. Thus for 10 cm. of sea water the absorption coefficient approximates 0·25.

Combining the above analyses indicates that the total absorption coefficient for 10 cm. of sea water and the glass bottles is 2·10. From the foregoing equation the intensity of the biologically effective ultraviolet within the bottle is calculated as 0·8 % of the intensity incident to the sea-water surface.

ZoBell and McEwen (1935) exposed shallow layers of filtered sea water in glass vessels to direct midsummer sunlight at La Jolla, California. The experiment was conducted so that the maximum effect of sunlight at this latitude could be observed. At a depth of 2 mm., two hours were required to effect a population reduction of approximately 50 %.

If the time-energy relationship of the Bunsen-Roscoe law holds, the time required for a comparable reduction of bacteria in the typical light and dark bottle experiment would amount to 250 hours with a zenith sun over calm, clear sea-water. Actually ZoBell and McEwen's data do not conform to the Bunsen-Roscoe law in that the bactericidal action of sunlight was limited to the first few minutes of exposure. On this basis the chance of detecting any significant bactericidal action in light and dark bottle experiments would be negligible.

Two experiments were designed to compare growth and oxygen consumption for sea-water suspensions of bacteria in light and dark bottles.

Experiment I.

Vineyard Sound sea water was collected at a site two miles from the nearest shore. The sample was quickly transported to the laboratory and passed through a millipore filter to remove plankton and particulate matter. The filtrate was seeded with a mixed population of bacteria obtained from a 24-hour plate culture of Vineyard Sound water. The initial bacterial count and dissolved-oxygen content were determined and the sample was siphoned into a series of light and dark 250 ml. standard dissolved-oxygen bottles. The bottles were filled to capacity so that the ground-glass stoppers made an air-tight seal with the sea water.

Half of the light and dark bottles were exposed to sunlight in the bottom of a tray suspended 10 inches below the surface of the water from a floating dock at Woods Hole. The bottles were laid parallel to the bottom and precautions were taken to avoid shadow interference.

The remaining light and dark bottles were illuminated with fluorescent lights in a white-painted tray cooled by a continuous flow of tap water. The distance of the submerged bottles to the light source was about 12 inches and the incident light intensity measured 1000 ft.-candles. The temperature of the tap water was 20 ± 2°C.

The experiment was conducted in July when the daily duration of sunlight approached 15 hours. Some precipitation occurred during the first 24 hours; otherwise clear weather prevailed. The period of exposure on the dock started about 10 a.m. and photometer measurements were taken by pointing a photo-electric cell, held over the tray, directly at the zenith. The maximum sunlight intensities were generally encountered about midday and amounted to 5,000 to 8,000 foot-candles while the minimum midday readings during cloudy conditions were about 1,000 foot-candles. The recorded temperature of the sea water was 22 ± 2°C.

Periodically a pair of light and dark bottles was removed from each tray and analysed for total bacterial count by the plating method and for dissolved-oxygen content by the Winkler method. The bacterial sample (1 ml.) was always removed first but only after releasing cells adhering to the inner walls of the bottle by scrubbing with a rubber policeman, care being taken to avoid the introduction of oxygen in the form of air bubbles.

Nutrient sea-water agar of the following composition was the media of choice:—

Aged sea water	1000 ml.
Bacto-peptone	5 gram.
Glucose	1 gram.
K_2HPO_4	·05 gram.
Bacto-agar	15 gram.

Appropriate dilutions were made so that the plates selected for counting after 5 days incubation at room temperature contained 30—300 colonies.

Table 1.

Average bacterial counts and dissolved-oxygen content of millipore-filtered sea water inoculated with marine bacteria and exposed to sunlight and artificial light in light and dark bottles.

	Sunlight				Artificial Light			
	Light Bottles		Dark Bottles		Light Bottles		Dark Bottles	
Time, hrs.	Cells per ml.	D. O. ml./l.	Cells per ml.	D. O. ml./l.	Cells per ml.	D. O. ml./l.	Cells per ml.	D. O. ml./l.
0	$2{\cdot}1\times10^3$	4·12	$2{\cdot}1\times10^3$	4·12	$2{\cdot}1\times10^3$	4·12	$2{\cdot}1\times10^3$	4·12
5	$1{\cdot}6\times10^4$	3·90	$4{\cdot}4\times10^4$	4·12	$4{\cdot}4\times10^4$	4·13	$3{\cdot}1\times10^4$	4·13
24	$2{\cdot}7\times10^5$	3·84	$2{\cdot}8\times10^5$		$2{\cdot}9\times10^5$	3·91	$5{\cdot}7\times10^5$	3·80
30	$3{\cdot}7\times10^5$	3·95	$7{\cdot}9\times10^5$	3·90	$5{\cdot}1\times10^5$	3·91	$5{\cdot}3\times10^5$	3·86
70	$1{\cdot}8\times10^5$	3·80	$1{\cdot}0\times10^6$	3·85	$6{\cdot}6\times10^5$	3·81	$1{\cdot}1\times10^6$	3·85
76	$2{\cdot}5\times10^5$	3·80	$3{\cdot}6\times10^5$	3·72	$4{\cdot}2\times10^5$	3·85	$7{\cdot}6\times10^5$	3·80

Table 1 relates the total bacterial counts to the dissolved-oxygen concentrations for this experiment. The absence of a phytoplankton population permitted the measurement of bacterial respiration in the absence of photosynthesis. It also obviated the possibility of obscure reactions between the two populations.

From an initial count of 2×10^3 cells/ml., the populations increased over the first 30 hours to about 5×10^5 cells per ml. Maximum populations were reached within 70 hours, at which time the numbers of bacteria in the dark bottles exceeded the total counts in the light bottles by almost an order of magnitude. However, at 76 hours the populations were essentially the same in all bottles.

The limit of sensitivity for the Winkler dissolved-oxygen method is approximately $\pm$ 0·05 ml./l. Thus a difference between any two samples of less than 0·10 ml./l. is not considered significant. The dissolved-oxygen concentration gradually decreased from 4·12 ml./l.

to about 3·80 ml./l. over a period of 76 hours. A comparison of the corresponding light and dark bottles reveals that with a single exception the light-bottle concentrations were never significantly higher than the related dark-bottle concentrations. The difference of 0·11 ml./l. between the light and dark bottles after 24 hours exposure under artificial light is inconsistent with the other observations and probably spurious.

Experiment II.

Sea water from Vineyard Sound was paper-filtered to remove the grosser particulate matter and dispensed into light and dark bottles, which were suspended off the Woods Hole dock. Here a study was made of the natural bacterial population in the presence of phytoplankton.

Table 2.

Average bacterial counts and dissolved-oxygen content of paper-filtered sea water in light and dark bottles as influenced by sunlight.

Time, hrs.	Light Bottles		Dark Bottles	
	Cells per ml.	D. O. ml./l.	Cells per ml.	D. O. ml./l.
0	$3·1\times10^3$	4·50	$3·1\times10^3$	4·50
7	$7·9\times10^3$	4·55	$4·5\times10^3$	4·45
24	$2·8\times10^5$	4·36	$2·2\times10^5$	4·31
31	$3·2\times10^5$	4·64	$2·7\times10^5$	
48	$3·4\times10^5$	4·71	$4·8\times10^5$	4·21
55	$1·9\times10^5$	4·80	$3·8\times10^5$	3·50
127	$1·5\times10^5$	5·02	$1·5\times10^5$	3·82
151	$6·8\times10^4$	4·83	$1·9\times10^4$	

Photosynthesis caused a gradual increase in the dissolved oxygen content of the light bottles indicating an excess of oxygen production over respiration. However, as shown in Table 2 the results are in agreement with Experiment I in that the growth of bacteria was essentially the same in the light and dark bottles.

Summary.

1. The majority of wave-lengths shorter than 350 mμ are effectively absorbed by glass bottles commonly used in this and other laboratories for dissolved-oxygen determinations.
2. Solar radiations transmitted by these bottles at a depth of 10 inches below the sea surface had no demonstrable lethal effects on suspensions of marine bacteria in sea water.
3. Bacteriological evidence is presented that the oxygen method of measuring photosynthesis is valid for experiments covering more than 24 hours.

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A Comparison of the Oxygen and ^{14}C Methods of Measuring Marine Photosynthesis.[1] [2]

By

J. H. Ryther and **R. F. Vaccaro,**
Woods Hole Oceanographic Institution.

Introduction.

An experimental method of measuring photosynthetic rates of natural populations of phytoplankton was first described by Gaarder and Gran (1927). This method involves measuring the rate of oxygen production by the phytoplankton from the difference in the dissolved-oxygen content of sea-water samples enclosed in "light" (transparent) and "dark" (opaque) bottles. In the light bottle, the net effect of both photosynthesis and respiration is measured, while the dark bottle measures respiration alone. Assuming that respiration of the native flora and fauna is essentially the same in the light and dark bottles, the difference in their dissolved-oxygen concentrations after a given experimental period may be considered equal to the oxygen produced by photosynthesis.

Recently, a new technique for measuring photosynthesis was described by Steemann Nielsen (1951b, 1952). In this method, the rate of uptake of radio-active carbon by the phytoplankton is determined by adding small quantities of ^{14}C as carbonate to sea-water samples, removing the plankton after a given experimental period by filtration, and measuring its radio-activity. If the ratio of uptake of $^{14}C : {}^{12}C$ is known, a direct measurement of carbon assimilation may thus be obtained.

The Gran oxygen method, or slight modifications thereof, has found rather widespread use among marine biologists. The most significant studies are perhaps those of Steemann Nielsen (1951a and references) in coastal waters off Denmark, and Riley (Riley

[1] Contribution No. 684 from the Woods Hole Oceanographic Institution.

[2] This work was carried out with the assistance of a research grant from the National Science Foundation and under contract with the Office of Naval Research.

et al., 1949 and references) in the coastal and offshore waters of the north-western Atlantic.

The ^{14}C method was used by Steemann Nielsen to measure the production rate of organic matter in all of the major oceans of the world during the recent "Galathea" expedition. A comparison between some of his results from the "Galathea" cruise and Riley's earlier figures obtained with the oxygen method showed reasonably good agreement in coastal, eutrophic waters. However, Riley's values from the tropical Atlantic (i.e., Sargasso Sea) were considerably higher than those obtained by Steemann Nielsen for the tropical regions of the Indian Ocean (see Steemann Nielsen, 1952).

Although the reasons were not made clear why photosynthetic rates in two different oceans at two different times should agree, even to an order of magnitude, the discrepancy between the two sets of data led Steemann Nielsen to question the oxygen method as a technique for measuring photosynthesis in the open ocean. In defence of his data Riley (1953) has pointed out that the apparent discrepancy resulted largely from the respective choice of average photosynthesis values by the two workers, and that the actual range of values obtained in each case was very nearly the same.

This difference of opinion has cast doubt both upon earlier measurements of marine photosynthesis and upon the classical oxygen method as a tool for future studies. Steemann Nielsen's principal argument is based upon the contention that bacterial respiration in light and dark bottles is not equal, due to the bactericidal effects of sunlight. This hypothesis has been investigated by the present authors and is reported elsewhere (Vaccaro and Ryther, 1954). The need remains apparent, however, for a simultaneous comparison of the two methods. This report contains the results of some experiments in which such a comparison was made.

Methods.

Photosynthesis was measured by the oxygen and ^{14}C methods in cultures of the diatom, *Nitzschia closterium*, and in natural phytoplankton populations from Vineyard Sound.

Experiments were conducted in 250 ml. glass-stoppered bottles under artificial illumination provided by eight 40-W. fluorescent lamps, which produced an intensity of 1000 foot-candles incident to the bottles. The latter were completely immersed in circulating tap-water in a white-painted tray. The temperature of the cooling water ranged from 18° to 22°C.

Oxygen experiments.

Cultures of *Nitzschia* were centrifuged from their nutrient media and resuspended in filtered sea water collected from Vineyard Sound during June and July. Equal volumes of *Nitzschia* suspension containing varying cell concentrations were added to the experimental bottles, which were then carefully filled by siphon with filtered sea water.

In each experiment, three bottles were employed, the first used for an immediate determination of dissolved oxygen, the second placed in the water tray exposed to light, and the third wrapped in a black cloth bag, which was also completely immersed in the water bath. At the conclusion of the experimental period, the latter two bottles were removed and their dissolved-oxygen content measured. Differences between the oxygen concentrations of the light and dark bottles were considered to be equal to the oxygen produced by photosynthesis in the experiment. The glucose-carbon equivalent was obtained by multiplying the weight of the produced oxygen by 0·375.

The oxygen method, as described above, is subject to a basic source of error in that respiration of the phytoplankton in the light bottle is probably always somewhat higher than that in the dark bottle. This will obviously be so if there is any appreciable growth of the organisms in the light bottle. However, even if no cell division occurs, the conversion and metabolism of newly formed products of photosynthesis may result in a considerably higher respiration rate in the light bottle, particularly in the case of experiments lasting for several days. As a consequence of this "after effect of photosynthesis upon respiration", as it is described by Rabinowitch (1945), the estimate of respiration in the light bottle based upon that measured in the dark bottle is too low, resulting in correspondingly low values for photosynthesis.

^{14}C experiments.

^{14}C in the form of barium carbonate was converted to sodium carbonate and used in the synthesis of an artificial sea water in the same manner as described by Steemann Nielsen (1952), and the solution was sterilized by autoclaving. The activity of a diluted aliquot was then determined by re-precipitation as $Ba^{14}CO_3$ which was filtered and measured for activity corrected to zero thickness of sample, again following the method prescribed by Steemann Nielsen. Activity of the stock solution was $1{\cdot}39 \times 10^6$ cpm. per ml.

One ml. aliquots of the ^{14}C stock were added to the experimental bottles which were inoculated with *Nitzschia* and filled with filtered sea water, as in the light and dark bottle experiments. These were then placed in the water-bath exposed to the light.

At the conclusion of the experimental period the samples were filtered through a hydrosol millipore filter[1]) capable of retaining all particulate matter above 0·5 μ in diameter. The filters were cut to size so that they could be mounted on a precipitation apparatus[2]) for filtration and on planchet holders for measurement of their activity. After the filtration, the filter was washed with 25 ml. of sea water and 10 ml. of 0·001 M HCl. The latter was found to be considerably faster than, and equally as efficient in removing traces of inorganic ^{14}C as, Steemann Nielsen's method of exposing the filters to fumes of

[1]) Lovell Chemical Co., Watertown, Mass.
[2]) E8-A precipitation apparatus: Tracer Lab. Inc., Boston, Massachusetts.

concentrated HCl. The filters were then mounted on planchet holders and dried for 24 hours or to constant activity in a desiccator containing silica gel. Their activity was measured with a Tracerlab SC-16 windowless flow-counter to an accuracy of $\pm 1\ ^0/_0$.

The total CO_2 content of the sea water was determined from its temperature, pH, and salinity at the time it was dispensed into the experimental vessels from the equations of Buch, Harvey, Gripenberg, and Wattenberg (see Harvey, 1945). This was multiplied by the ratio of ^{14}C assimilated (activity of the filtered plankton) : ^{14}C available ($1{\cdot}39 \times 10^6$ cpm.), giving a first approximation of total CO_2-assimilation by the phytoplankton.

To obtain an accurate determination of photosynthesis from the above figure, the following sources of error, as discussed by Steemann Nielsen, must be corrected for:—

1. The isotope effect (i.e., the difference between the rate of uptake of ^{14}C and ^{12}C). On the basis of evidence presented by Steemann Nielsen and references cited by him, the ratio of $^{12}C : {}^{14}C$ assimilation is taken as 1·06 : 1, thus requiring a correction of $+6\ ^0/_0$ to be applied to the initial value.
2. The uptake of ^{14}C by processes other than photosynthesis. Uptake of ^{14}C in the dark by *Nitzschia* was found to equal approximately $1\ ^0/_0$ of that observed in the light in both 6- and 24-hour experiments and in different concentrations of *Nitzschia*. This is in good agreement with Steemann Nielsen's figures for *Scenedesmus*, and results in a correction factor of $-1\ ^0/_0$.
3. The loss of assimilated ^{14}C by respiration during the course of the experiment. This is a difficult figure to estimate, since it will vary not only with the length of the experimental period, but also with the rates of photosynthesis and respiration of the organisms. Steemann Nielsen has placed this at $4\ ^0/_0$ of total photosynthesis for a 4-hour experiment, although his basis for doing so is not clear. In view of the lack of evidence concerning this question and the difficulties involved in obtaining such measurements, no attempt will be made here to correct for this source of error.

A total correction of $+5\ ^0/_0$ is therefore applied to the calculated CO_2-assimilation, as described above, and it is emphasized that this figure will fall below the true value for CO_2-assimilation by the uncorrected loss of respired ^{14}C.

Sensitivity of the oxygen and ^{14}C methods.

Duplicate samples analysed for dissolved oxygen by the Winkler method gave values which were generally reproducible to $\pm 0{\cdot}05$ ml. O_2/l. In the experiments described below differences between the dissolved-oxygen concentrations of the light and dark bottles of less than 0·10 ml./l. were not considered significant. This corresponds to a carbon assimilation of 0·054 mg. C/l., which may be considered the lower limit of sensitivity of the method as here used.

In the ^{14}C experiments, it was found that if 1 ml. of ^{14}C stock

were added to the sea water and the latter filtered immediately, the filtered material showed an activity which varied considerably but averaged 50 cpm. above the normal background of approximately 25 cpm. This activity persisted after the filter was washed with dilute HCl or exposed to HCl fumes, and was not removed by filtering the ^{14}C stock through a millipore filter immediately before the experiment. While its cause is not understood, it was found to be directly proportional to the activity of the ^{14}C stock and is believed to result from contamination. Because of the variability of this "blank", activities of less than 150 cpm. were not considered to be significant.

Assuming an average total carbon content of sea water of 24·5 mg./l., the lower limit of sensitivity of the ^{14}C method was therefore 0·0013 mg. C/l. or $^1/_{40}$th that of the oxygen method.

Experiments.

Three series of experiments were conducted in which the photosynthetic rates of various concentrations of *Nitzschia* were measured by the oxygen and ^{14}C methods for experimental periods of 6, 24, and 48 hours. *Nitzschia* concentrations were determined from hemacytometer counts and were expressed as the equivalent weight of carbon. The data for this conversion were obtained by centrifuging the cells from a one-litre culture of *Nitzschia*, of known cell-concentration, and drying to a constant weight at 60°C. The figure obtained ($3·2 \times 10^{-11}$ g./cell), although based upon a single analysis, showed good agreement with those of Riley (1943) and Ketchum and Redfield (1949) for the same organism. Using Ketchum and Redfield's elementary analysis of *Nitzschia*, its carbon content is 55 % of the dry weight, or $1·76 \times 10^{-11}$ g./cell.

Nitzschia concentrations in these experiments ranged approximately from 0·025 to 3·0 mg. C/l., which corresponds roughly with phytoplankton concentrations which might be expected in situations ranging from tropical ocean waters to coastal blooms (see Riley *et al.*, 1945, p. 44).

Photosynthesis rates are expressed as the weight of glucose-carbon synthesized per day, on the assumption of a 12-hour day-light day, and are illustrated in Figure 1.

Measurements of photosynthesis could not be made by the oxygen method at the lower concentrations of *Nitzschia* in the 6- and 24-hour experiments, since there was no significant difference between the dissolved-oxygen content of the light and dark bottles. At higher concentrations of the diatom, where photosynthesis could be measured by both methods, agreement between them was extremely good. In the 48-hour experiment, on the other hand, values obtained by the ^{14}C method were appreciably lower than those given by the oxygen method. This discrepancy is believed to be largely due to the uncorrected loss of ^{14}C by respiration, as discussed earlier. In 48 hours this may have represented a considerable fraction of the assimilated ^{14}C, particularly since the photosynthetic rate became reduced in the experiment. The

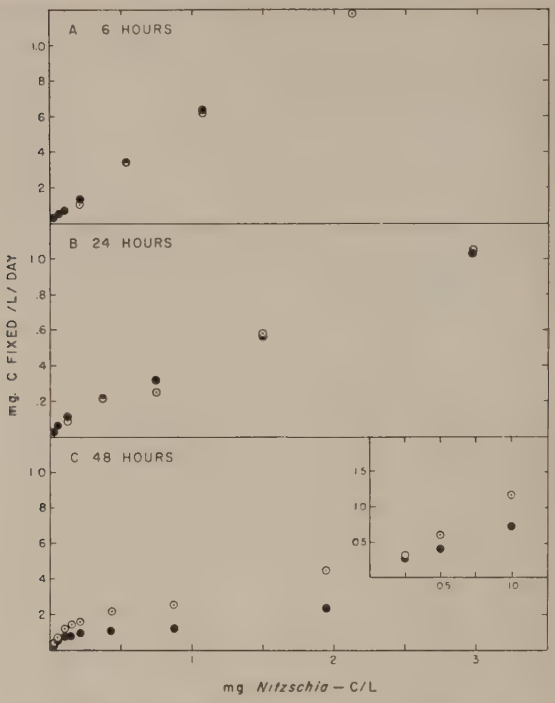

Figure 1. The relation between the concentration of *Nitzschia* and its rate of photosynthesis as measured by the oxygen method (open circles) and the ^{14}C method (closed circles).

discrepancy can hardly be attributed to an inaccuracy of the oxygen values, since any errors inherent in the oxygen method appear to result in the underestimation of photosynthesis.

The linear relationship between photosynthesis and diatom concentrations observed in the 6-hour experiment indicates that, within the range of concentrations studied, photosynthesis per unit of *Nitzschia* proceeded at a constant rate. In the 24-hour experiment, however, a decrease in the photosynthetic rate (mg. C fixed / mg. *Nitzschia*-C) was observed at a concentration of 0·125, but this rate then appeared to remain constant between 0·125 and 2·980 mg. C. In the 48-hour experiment, the steady decrease in the photosynthetic rate with increasing *Nitzchia* concentrations clearly indicates that nutrient exhaustion or some other factor became limiting to photosynthesis. Here the oxygen method gave measurable values for photosynthesis at the lower concentrations of the diatom and indicates a linear relationship between photosynthesis and concentration only within the range 0·025—0·100 mg. *Nitzschia*-C/l. (see insert in Figure 1, C).

A comparison of the photosynthetic rates observed in the three experiments of different duration is not advisable since the *Nitzschia* used in each experiment came from a different culture, which was in a different growth-phase. R i l e y (1943) has demonstrated that photosynthesis of *Nitzschia* varies considerably with its growth-rate.

Therefore, another experiment was conducted in which only one concentration of the diatom was used and photosynthesis was measured at different intervals of time, from 6 to 96 hours. In each case the rate of photosynthesis was determined for the entire experimental period and then calculated on a daily basis. To avoid the exhaustion of

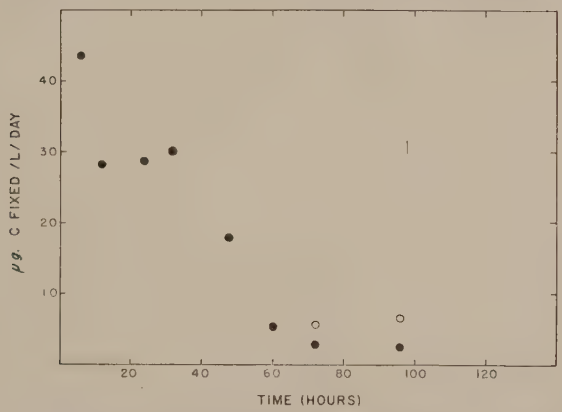

Figure 2. The relation between the duration of the experiment and the measurement of the photosynthetic rate of *Nitzschia* (0·04 mg. C/l.) by the oxygen method (open circles) and the ^{14}C method (closed circles).

nutrients early in the experiment, a relatively low concentration of 0·14 mg. *Nitzschia*-C/l. was used.

The results of this experiment are illustrated in Figure 2. Here it is apparent that the photosynthetic rate as measured by the ^{14}C method decreased irregularly but definitely as the duration of the experiment increased, from 0·044 mg. C/l./day at 6 hours to 0·004 mg./l./day at 96 hours.

The oxygen method gave significant photosynthesis values only at 72 and 96 hours. These were considerably higher than the corresponding ^{14}C values measured at the same time, illustrating the loss of ^{14}C by respiration in the latter. However, the oxygen values were also much lower than the 6-hour ^{14}C value, indicating that an actual reduction of photosynthesis did occur.

A somewhat similar time-study was made using, in place of *Nitzschia*, raw sea water, containing its natural plankton, collected from Vineyard Sound in July 1953. This water was divided into two portions, the first of which was untreated, while the second was enriched with N, P, Si, and Fe. The photosynthetic rates occurring in both the

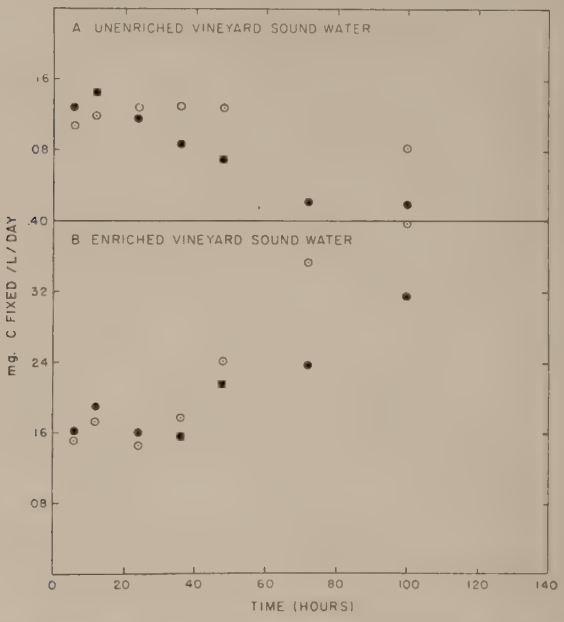

Figure 3. The relation between the duration of the experiment and the measurement of the photosynthetic rate of a natural plankton population by the oxygen method (open circles) and the ^{14}C method (closed circles).

enriched and unenriched water were measured by the two methods for periods of 6 to 100 hours and expressed as the rate per day, as in the preceding experiment (Figure 3).

In both enriched and unenriched water good agreement was observed between photosynthesis measurements obtained by the two methods from 6 to 24 hours. From 24 to 100 hours the ^{14}C method gave increasingly lower values than the oxygen method.

In the enriched water, both methods showed an increase in photosynthesis per unit of time as the experiment progressed, corresponding to growth of the contained phytoplankton. However, while photosynthesis per day measured by the oxygen method showed an increase of over 150 % at 100 hours over that observed at 6 hours, a corresponding increase of only 100 % was observed by the ^{14}C method.

In the unenriched water, the photosynthetic rate as measured by the oxygen method remained roughly constant for the entire 100 hours, while measurements by the ^{14}C method showed a steady decrease with time after 24 hours, with a photosynthetic rate at 100 hours less than 25 % of that observed at 6 hours.

In this experiment, the discrepancy between the values obtained by the two methods is again believed to result principally from ^{14}C lost by respiration.

Discussion.

The experiments described above substantiate Steemann Nielsen's contention that comparable photosynthesis measurements may be obtained by both the oxygen and ^{14}C methods in eutrophic ocean waters. However, if photosynthetic rates are relatively low, use of the oxygen method is possible only if employed for rather long-term experiments (48 hours or more) while the more sensitive ^{14}C method may still usually find application in 6- to 12-hour experiments.

No evidence was found to substantiate Steemann Nielsen's claim that oxygen experiments conducted for periods of more than 24 hours give unrealistically high values. On the contrary, such values were often appreciably lower than those obtained by 6-hour ^{14}C experiments. This is undoubtedly due in part to errors inherent in the oxygen method, but is probably also a reflection of a real reduction of the photosynthetic rate which must inevitably occur over a period of time in an enclosed sample of sea water containing a limited supply of nutrients.

The ^{14}C method does not appear to be suitable for measuring photosynthesis in experiments of more than 24 hours duration, due to the loss of assimilated ^{14}C by respiration. As discussed earlier, this factor is undoubtedly affected by several variables and hence cannot be accurately estimated. The observed differences between photosynthetic rates obtained by the two methods in the experiments described above are believed to result from this source of error. Furthermore, the discrepancy between the two sets of data tends to minimize the error, since values obtained by the oxygen method were themselves probably somewhat lower than the true photosynthetic rates.

If ^{14}C experiments are limited to 24 hours or less, the loss of assimilated ^{14}C by respiration does not appear to be significant. In view of Steemann Nielsen's success in obtaining measurements of photosynthesis in tropical ocean waters with 6-hour ^{14}C experiments, the preceding discussion would appear to be of academic interest. However, these authors were unable to detect significant ^{14}C assimilation in the Sargasso Sea during August in 24-hour experiments under 1,500 foot-candles of illumination, using ^{14}C stock with an activity of $1{\cdot}39 \times 10^6$ cpm. While this difficulty might have been somewhat overcome by using ^{14}C of greater activity, the latter would increase errors caused by contamination, as discussed earlier, thereby reducing both sensitivity and accuracy. Thus conditions may exist in the oceans under which photosynthesis may not by accurately measured even by the ^{14}C method.

Summary.

1. Measurements of phytoplankton photosynthesis rates by the oxygen and ^{14}C methods gave comparable values in 6- to 24-hours experiments where photosynthetic activity was great enough to be measured by both methods.
2. Under conditions of reduced photosynthesis the more sensitive ^{14}C

method usually permitted measurements within 6—24 hours, while the oxygen method required an experimental period of several days.

3. Oxygen experiments of more than 24 hours duration gave values which compared favourably with those obtained from 6-hour ^{14}C experiments, provided that the rate of photosynthesis remained constant during the entire experiment. If nutrients or other factors became limiting to photosynthesis, such long-term experiments gave values appreciably lower than 6- to 24-hour measurements by either method.
4. ^{14}C experiments conducted for periods of more than 24 hours gave values considerably lower than oxygen experiments of the same duration, presumably due to the loss of assimilated ^{14}C by respiration. In the absence of sufficient information to correct for this error, the ^{14}C method is not recommended for use in long-term experiments.

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Mesh Selection in the Roundfish Seine.

By

C. E. Lucas, A. Ritchie, B. B. Parrish,

and **J. A. Pope,**

Marine Laboraty, Aberdeen.

Introduction.

Most of our knowledge of mesh selection is based on data derived from the deep-sea trawl net. However, the Danish seine net has for many years been an important gear for capturing flatfish, and during the last thirty years a similar net has been modified progressively for catching roundfish, particularly in the Scottish fishery. It has become increasingly necessary, therefore, to have an understanding of mesh selection in this net.

Not unnaturally, perhaps, the general tendency has been to assume that the selection properties are similar to those of the trawl. There is very little reference to this subject in the literature, although the results obtained by Bowman (1928) point to a difference. Jensen (1949), in his review of mesh selection, suggested a difference in selectivity between the seine and trawl for flatfish, but he considered that further work was necessary, particularly for roundfish. Margetts (1949) presented further data on length composition of catches by seine and trawl fishing side by side, and he concluded that there is, on the evidence available, a difference in the selection of dabs and plaice. The whole evidence published to that date has been reviewed recently by Graham, Beverton, Margetts, and Gulland (1954; a paper on this subject was presented to the International Council for the Exploration of the Sea in 1953). They concluded that "there is an overall difference in the selective effect of the two gears, with the seine liberating relatively larger fish than does the trawl". Although the available data referred chiefly to plaice, they considered there were indications that this generalization applies also to dabs and haddock.

Meanwhile, new data on the selectivity of seines with cod-end meshes of different sizes have been acquired by the Marine Laboratory, Aberdeen, since the end of the war, particularly during 1953. This work constitutes part of an extended programme of fishing gear investigations being undertaken at that Station. Preliminary results obtained during 1949—1952 were indicative of a real difference in selectivity between trawl and seine, particularly for roundfish, and accordingly a larger experiment was undertaken in June 1953, in which two commercial seiners were chartered by the Scottish Home Department to fish one against the other on the same grounds. This experiment substantiated the 1949—1952 results.

A more detailed experiment was then undertaken in August and September 1953, again with the two commercial seiners. On this occasion the seiners fished in close co-operation with a research vessel and a commercial trawler in order to provide comparative data. In a large number of the hauls the seine cod-ends were covered with small-mesh sprat netting to catch escaping fish, thus giving direct measures of the selectivity.

This paper deals with the haddock and whiting data obtained during the August and September experiment. The length compositions of haddock catches taken by seines with different cod-end meshes are examined, while the selection characteristics of each cod-end are compared with those of the trawl for both haddock and whiting. The results are discussed in association with girth measurements of haddock and whiting. Details of the girth-length relationships are given in the Appendix.

Parallel work was also undertaken by the Fisheries Laboratory, Lowestoft, and the results are dealt with by G r a h a m in an associated paper (1954).

Gear.

The seines used in the August and September experiment were of the type commonly employed in the seine net fisheries off the Scottish east and west coasts. Their chief dimensions were as follows:—

Length of Headline = 68 yds.
" " Wings = 28 yds. (average mesh size = 120 mm.)
" " Shoulder = 6 yds.
" " Funnel = 18 yds. (mesh size as for cod-end)
" " Cod-end = 7 ft. 6 in. (included in funnel)
Depth at Shoulder = 28 ft. 6 in.
Twine: Cod-end, 12/24 ply
Remainder of Funnel, 12/12 ply.

The trawls used for comparison conformed with those of North Sea trawlers fishing from Aberdeen. They were braided with 112's gauge tarred manilla twine, double in the cod-end.

Seine cod-ends of three different mesh sizes were purchased for the experiment. Measurements (with a spring gauge) of the fully stretched

Table 1. Length frequency distribution of haddock caught in cod-end of 70 mm. otter trawl.

Length (cm.)	Total numbers caught	Number per 10 hours (slide rule accuracy)	Frequencies smoothed in 3's
20	8	5	11
21	41	27	36
22	115	77	95
23	273	182	179
24	419	279	243
25	400	267	240
26	260	173	175
27	126	84	103
28	80	53	60
29	65	43	49
30	78	52	47
31	67	45	49
32	73	49	42
33	50	33	36
34	41	27	26
35	26	17	19
36	18	12	13
37	14	9	10
38	12	8	6
39	2	1	3
40	3	1	1
41	2	1	1
42	2	1	1
43	3	1	1
44	3	1	1
45	2	1	1
46	2	1	1
47	—	—	—
48	—	—	—
49	—	—	—
50	1	—	—
>50	5	3	—
Total	2191	1453	

"between knot" mesh sizes showed little change in size during the course of the experiment. Mean sizes were as follows:—

Net	Mean Measured Size of Cod-end	Range of Means
1	59 mm.	57—61 mm.
2	71	69—73
3	80	77—82

As a convenient approximation these cod-ends will be referred to hereafter as 60, 70, and 80 mm. cod-ends respectively. It is important to note that the funnel mesh in each case corresponded with that of the cod-end.

Results.

Various grounds were sampled during the experiment, but most of the material was obtained from grounds in 45 to 55 fathoms, 10 to 20 miles NxW of Kinnaird Head, on the Scottish north-east coast.

The two seiners worked in close proximity to one another throughout the experiment, and hauls were made according to a prescribed sequence, in which the nets and the cod-ends of different mesh sizes were frequently interchanged between the vessels. The gear was operated as in normal Scottish practice, i.e., from the unanchored vessel. The most complete comparison was made between the 70 and 80 mm. seines, with which 37 and 27 hauls were made respectively, all with a small-meshed cover attached to the cod-end. A small number of hauls (8) was also made with the 60 mm. seine interspersed between those with the 70 and 80 mm. nets. All haddock and whiting were measured by observers aboard each seiner, and counts and sample measurements were also made of other species taken in the catches. The trawl hauls, using 70 mm. cod-ends (range 63 to 75 mm., mean 70 mm.) were made as close as possible to the seiners and thus served to give the conventional picture of the fish stock present in the area. It is not intended in this paper to make a detailed comparison of the relative efficiencies of the two gears.

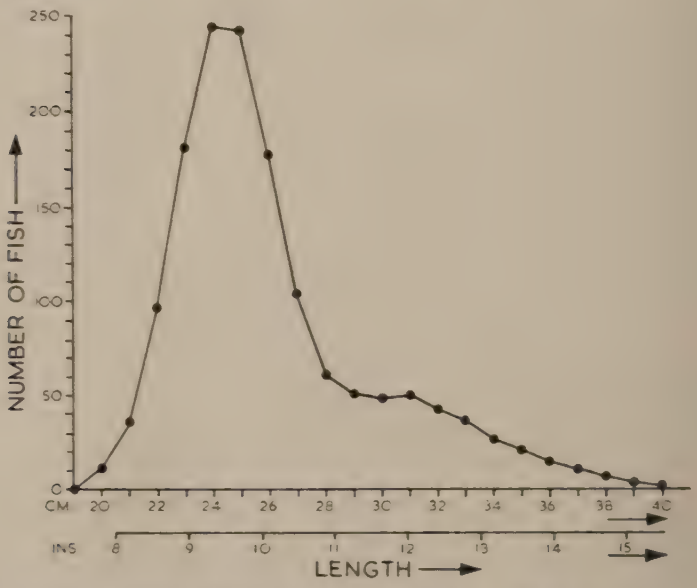

Figure 1. Length frequency distribution of haddock caught in cod-end of 70 mm. Otter trawl. Frequencies expressed as numbers per 10 hours' fishing (smoothed in 3's).

Table 2. Length frequency distributions of haddock caught by 70 mm. seine.

Length cm.	Total numbers caught in cod-end	Total numbers in cod-end plus cover	Numbers in cod-end per 6 hauls slide rule accuracy	Frequencies smoothed in 3's	Numbers in cod-end plus cover per 6 hauls slide rule accuracy	Frequencies smoothed in 3's
18	—	7	—	—	2	2
19	2	30	—	—	5	8
20	12	110	2	3	18	27
21	48	358	8	11	58	68
22	135	788	22	23	128	131
23	234	1278	38	39	207	200
24	358	1629	58	51	264	221
25	355	1185	58	54	192	194
26	276	772	45	45	126	130
27	194	445	31	39	72	87
28	247	396	40	44	64	73
29	383	514	62	62	83	84
30	516	644	83	80	104	102
31	590	696	95	86	118	104
32	498	563	81	80	91	93
33	397	435	64	63	71	69
34	268	281	43	45	46	49
35	178	182	29	28	29	29
36	75	76	13	18	13	18
37	65	65	11	10	11	10
38	34	34	5	7	5	7
39	25	25	4	4	4	4
40	18	18	3	3	3	3
41	13	13	2	2	2	2
42	5	5	1	1	1	1
43	1	1		1		1
44	2	2	1	—	1	—
45	1	1		—		—
46	—	—	—	—	—	—
47	—	—	—	—	—	—
48	—	—	—	—	—	—
49	—	—	—	—	—	—
50	—	—	—	—	—	—
>50	—	—	—	—	—	—
Total	4930	10553	799		1718	

The approximate size-composition of the haddock population sampled by the trawls is shown in Table 1 and Figure 1. The haddock stock was evidently of two main size-groups, a major one at 23 to 26 cm. and a less numerous one at 29 to 33 cm. There was no major change in the size composition of the catches throughout the period, and it may be concluded that a fairly uniform population of haddock remained on the grounds during the experiment.

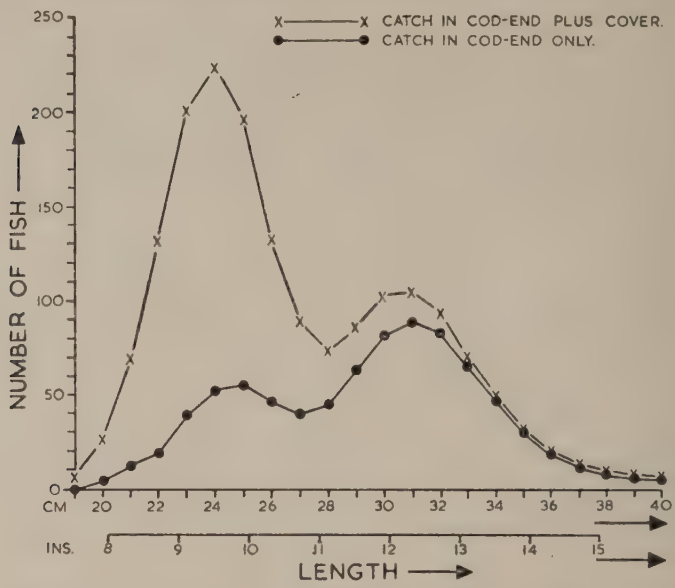

Figure 2. Length frequency distributions of haddock caught by 70 mm. seine. Frequencies expressed as numbers per 6 hauls (smoothed in 3's).

The size composition of the catches in the cod-end and in the cod-end plus cover of the 70 mm. seine is shown in Table 2 and Figure 2. It will be seen at once from the cod-end plus cover catches that the size composition of haddock entering the seine was approximately the same as that taken by the 70 mm. trawl. The seine graph has been drawn so that the frequencies at the most prominent mode correspond with those of the trawl. Two size-groups are again apparent, one at 23 to 26 cm., and the other at 29 to 33 cm. It is clear, however, that the size composition of haddock in the seine cod-end itself was very different from that of the trawl, fewer of the smaller size-group being retained. It is evident also from Figure 2 that haddock were escaping from the seine cod-end in large numbers over the 23 to 26 cm. size-range, and that in addition, escapes were taking place well above the minimum marketable size of 28 cm. The results from both gears therefore at once suggest a marked difference between the selectivity of the seine and trawl of the same cod-end mesh size.

Table 3 and Figure 3 show the size composition of haddock in the 70 and 80 mm. cod-end catches (excluding cover), together with that from the smaller number of hauls with the 60 mm. net (again excluding cover). These data show that by changing from 70 to 80 mm. seines, *in the population sampled,* there was a considerable reduction in the catch of all sizes up to 36 cm. This was very apparent amongst marketable as well as unmarketable fish. Whilst the small number of hauls

Table 3. Length frequency distributions of haddock in seine catches with 60, 70, and 80 mm. cod-ends.

Length (cm.)	Total numbers caught			Numbers per 25 hauls			Frequencies smoothed in 3's		
	60 mm. (8 hauls)	70 mm. (37 hauls)	80 mm. (27 hauls)	60 mm. (slide rule accuracy)	70 mm.	80 mm.	60 mm.	70 mm.	80 mm.
19	—	2	—	—	1	—	—	3	—
20	17	12	1	53	8	1	53	14	3
21	34	48	7	106	32	7	106	44	15
22	51	135	40	158	91	37	192	94	33
23	100	234	60	312	158	56	402	163	55
24	234	358	80	735	241	74	686	213	71
25	324	355	90	1010	240	83	885	222	74
26	290	276	70	909	186	65	807	186	76
27	161	194	88	501	131	81	582	161	76
28	108	247	89	337	167	82	416	185	94
29	131	383	130	410	258	120	407	258	127
30	152	516	195	475	350	180	489	336	143
31	186	590	188	582	400	128	554	362	138
32	193	498	156	604	336	105	539	334	114
33	138	397	116	432	266	108	467	261	100
34	117	268	105	366	182	97	346	189	93
35	75	178	79	241	120	73	255	118	70
36	51	75	43	159	51	40	162	72	49
37	27	65	36	85	44	33	94	39	28
38	12	34	12	37	23	11	47	28	18
39	6	25	10	18	17	9	24	17	10
40	6	18	11	18	12	10	13	13	8
41	1	13	6	3	9	6	8	8	6
42	1	5	2	3	3	2	5	4	3
43	3	1	2	9	—	2	7	1	1
44	3	2	—	9	1	—	7	—	1
45	1	1	2	3	—	2	4	—	1
46	—	—	2	—	—	2	1	—	1
47	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—	—	—
50	—	—	1	—	—	1	—	—	—
>50	—	—	—	—	—	—	—	—	—
Total	2422	4930	1621	7575	3327	1414			

with the 60 mm. seine does not allow the making of detailed comparisons, it is clear from Figure 3 that a reduction in mesh size from 70 to 60 mm. resulted in a marked increase in the catch of the unmarketable sizes.

For comparison and further confirmation, Table 4 and Figure 4 show another set of catches (32 hauls each by 64 and 80 mm. seine nets) from a different area in June 1953. The differences in size composition of these catches confirm in particular the losses of marketable haddock that may be incurred in increasing the mesh size to 80 mm.

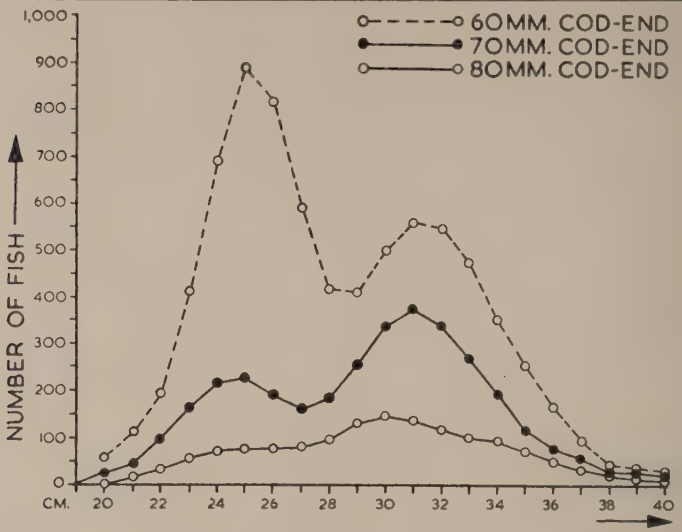

Figure 3. Length frequency distributions of haddock in seine catches with 60 mm., 70 mm., and 80 mm. cod-ends. Frequencies expressed as numbers per 25 hauls (smoothed in 3's).

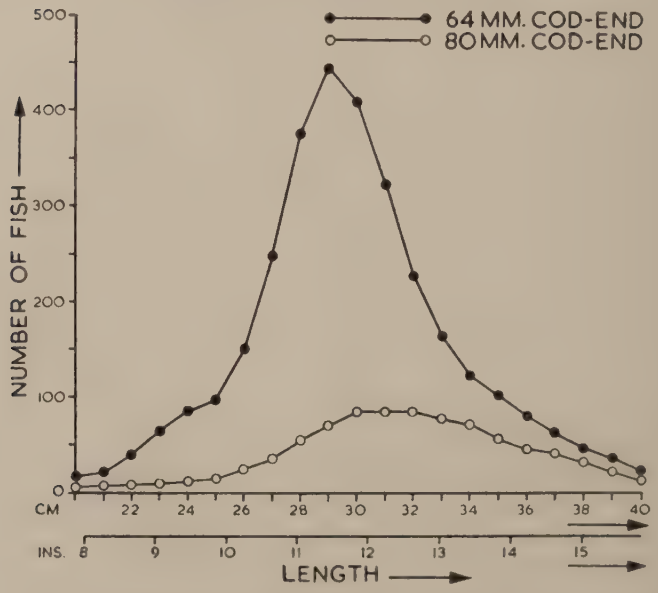

Figure 4. Length frequency distributions of haddock in seine catches with 64 mm. and 80 mm. cod-ends. Frequencies expressed as in Figure 3.

Table 4. Length frequency distributions of haddock in seine catches with 64 and 80 mm. cod-ends.

Length (cm.)	Total numbers caught		Numbers caught per 25 hauls		Frequencies smoothed in 3's	
	64 mm.	80 mm.	64 mm.	80 mm.	64 mm.	80 mm.
			(slide rule accuracy)			
16	1	—	1	—	1	—
17	4	—	3	—	4	—
18	11	—	9	—	9	—
19	21	1	16	1	15	1
20	25	1	20	1	16	1
21	16	1	13	1	20	3
22	33	7	26	6	38	4
23	97	7	76	6	63	5
24	113	4	88	3	83	6
25	107	13	84	10	97	11
26	152	24	120	19	150	23
27	288	50	227	39	247	35
28	501	59	393	46	374	54
29	643	98	502	77	440	69
30	544	109	425	85	410	84
31	387	114	303	89	321	85
32	301	103	236	80	228	84
33	187	107	146	84	166	79
34	150	93	117	73	122	72
35	132	74	103	58	102	59
36	112	60	87	47	82	49
37	73	55	57	43	66	42
38	70	45	55	35	48	32
39	40	23	31	18	37	25
40	31	27	24	21	24	14
41	22	4	17	3	20	11
42	23	13	18	10	17	7
43	20	10	15	8	13	9
44	9	11	7	9	10	8
45	9	7	7	6	6	6
46	4	5	3	4	5	4
47	6	2	5	2	4	3
48	4	4	3	3	3	2
>48	15	7	12	6	—	—
Total	4151	1138	3249	893		

The selective action of the 60, 70, and 80 mm. meshes was found to give even more pronounced differences for whiting, for which the minimum marketable size is 20 cm.

Differences in the selection properties of a cod-end may be conveniently measured by considering that length in the size-range of fish available at which a fish has approximately *a 50 % chance of being released or retained* (termed hereafter the 50 % release length). The

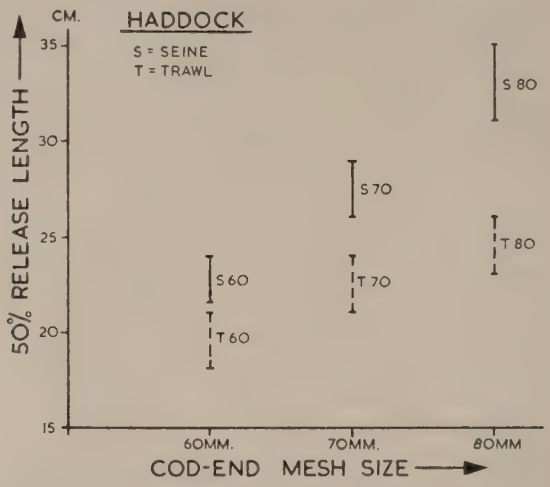

Figure 5. Relationship between observed 50 per cent. release lengths of haddock and mesh size for seine and trawl cod-ends.

ranges of haddock lengths within which the 50 % release lengths were found to lie for haddock for the 60, 70, and 80 mm. seine cod-ends are shown in Figure 5. They show a progressive increase and the range for each is quite separate from those of the others. Furthermore, these ranges are each quite different from the corresponding ranges within which the 50 % escape lengths of haddock have been found to lie for the trawl in a number of earlier experiments conducted from Aberdeen and elsewhere. These are also indicated in Figure 5 and the differences are quite distinct. Figure 6 shows the corresponding values for whiting together with the expected values calculated from the differences in head-girth between haddock and whiting (see below and Appendix, Table 5).

Looking at this from another point of view, we are really discussing how easy it is for a fish to slip through the mesh of the net; here we are concerned with the *girth* of fish, of which that of the *body* is both variable and compressible, while that of the *head* is much less so. It is considered that probably head-girth is the more important in determining whether a fish will pass through the mesh. Figure 7 shows the relationship between head-girth and total length for a sample of haddock of lengths between 21 and 56 cm., and whiting between 24 and 40 cm. (Appendix, p. 46).

Discussion.

It is evident from the Ministry of Agriculture and Fisheries film, "Trawls in Action", that the meshes in the cod-end are quite rigid and

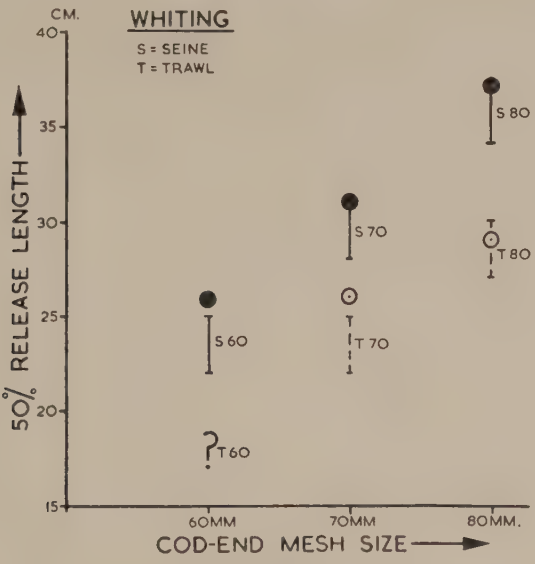

Figure 6. Relationship between observed 50 per cent. release lengths of whiting and mesh size for seine and trawl cod-ends. Estimated values from regression equations (see Appendix) shown as follow:—
● = seine, ⊙ = trawl.

stiff when the trawl is towed at normal towing speeds. In contrast, it is clear from the Scottish Home Department film, "Fish and the Seine Net", that the seine cod-end meshes are much less rigid than those of the trawl; cotton twine as used in the seine is much finer than the sisal and manilla twine used in the trawl, whilst the seine moves relatively slowly as it rounds up the fish over an area of sea-bed.

If the meshes were simply free loops, then the maximum girth values for the 50 % release lengths would be approximately equal to the circumferences of the appropriate meshes. It is easy to assess these for each of the 60, 70, and 80 mm. meshes; they are approximately as follows:— 124, 144, and 164 mm. The head-girth/length relationship shows, for example, that the haddock lengths (Appendix, Figure 8) corresponding to each of these are appreciably greater than the corresponding experimentally determined 50 % release lengths for the seine net (Figures 5 and 6), and much greater than those for the corresponding deep-sea trawls. This seems to be a sensible result, for it is hardly to be expected that the seine-net meshes are perfectly limp and free to assume a circular shape during the fishing operation. Early in the process of fishing the water pressure makes them loosely diamond-shaped; then the tension tends to increase as the bag fills with fish and the speed of hauling increases (again shown by the film). Evidently the

shape of the seine mesh is less rigidly fixed during fishing than in the trawl and this permits the escape of fish with girths much nearer the maximum value than does the trawl mesh of the same size. It will be noticed from Figures 5 and 6 that the 50 % release lengths for whiting, both for trawl and seine, are higher than for haddock. This is in conformity with the results from the head-girth/length relationship, which shows a smaller mean head-girth at each length for whiting than for haddock (Appendix, Figure 7).

For the haddock and the whiting the seine-net results seem to be quite clear, both in the catch and selection differences between seines of different mesh sizes, and in their selection differences from the corresponding trawl selections. The data for other fish caught during these experiments are being examined. It is intended to present detailed results for all species concerned together with many other aspects of the work in another paper.

Meanwhile, it may be concluded that *for haddock and whiting* there are marked differences in *selectivity* between the seine and the trawl. The data illustrated in Figures 5 and 6 suggest that for equivalence in haddock and whiting selectivity the cod-end mesh of the deep-sea trawl should be between 10 and 15 mm. greater than that of the seine, for the range of mesh size considered here.

Appendix.

1. In order to determine the relationship between head-girth and length for haddock and whiting, measurements of these quantities were obtained from three sets of random samples of freshly caught fish taken at different times and in different areas during 1953. All measurements were taken to the nearest millimetre. The lengths were measured in the normal manner with a metre stick graduated in millimetres and the head-girths were obtained by winding a flexible tape, graduated in millimetres, round the head in the region of the pterotic bone.

Results obtained from these samples are treated separately, as there were significant differences between areas and times.

2. The first sample, collected during the early part of May 1953, in the Buchan Deeps area of the North Sea, consisted of 149 haddock and 150 whiting. In the case of haddock the lengths ranged from 21 to 56 cm., while for whiting the lengths ranged from 24 to 40 cm. A graphical analysis indicated a linear association between the two variates, head-girth and length, for both haddock and whiting.

The regressions of head-girth on length were obtained for both species in the usual way. The two regressions were then tested for equality (see, for example, R a o, 1952) and on the basis of this test, it was concluded that the regression lines could be regarded as parallel but not coincident. The equations of the fitted lines were:—

$$G_H = 0{\cdot}439\, L_H + 1{\cdot}02 \qquad (1)$$

$$G_W = 0{\cdot}439\, L_W - 0{\cdot}46 \qquad (2)$$

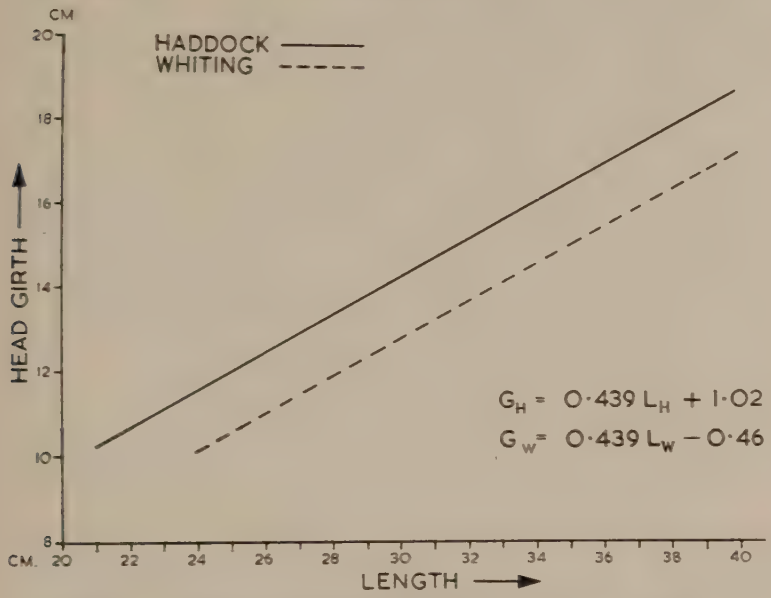

Figure 7. Regressions of head-girth on length for haddock and whiting caught in May 1953.

where G_H and L_H represent head-girth and length of haddock respectively (both in cm.) and G_W and L_W represent the same measures for whiting. These lines are shown graphically in Figure 7.

Equations (1) and (2) show that, for any given length in the range 24 to 40 cm., the head-girth of haddock in this sample was, on average, 1·5 cm. greater than that of whiting.

This means that if head-girth is a factor of primary importance in controlling release from a mesh, we should expect the 50 per cent. release length of whiting to be higher than that of haddock.

Reliable estimates of the 50 per cent. release lengths of haddock from trawl and seine nets are available (see Figure 5). With these it is then possible to estimate the corresponding expected release points for whiting. Thus if we take 25·5 cm. as the best estimate of the 50 per cent. release length of haddock for the 80 mm. cod-end of the deep-sea trawl, the corresponding head-girth from equation (1) is 12·2 cm. The 50 per cent. release length for whiting is then that value of L_W which corresponds to a value of G_W of 12·2 cm. This is to be estimated not from equation (2) but from the regression of L_W on G_W. This regression, which is parallel to the corresponding regression of L_H on G_H, was found to be:—

$$L_W = 2{\cdot}055\,G_W + 3{\cdot}87 \qquad (3)$$

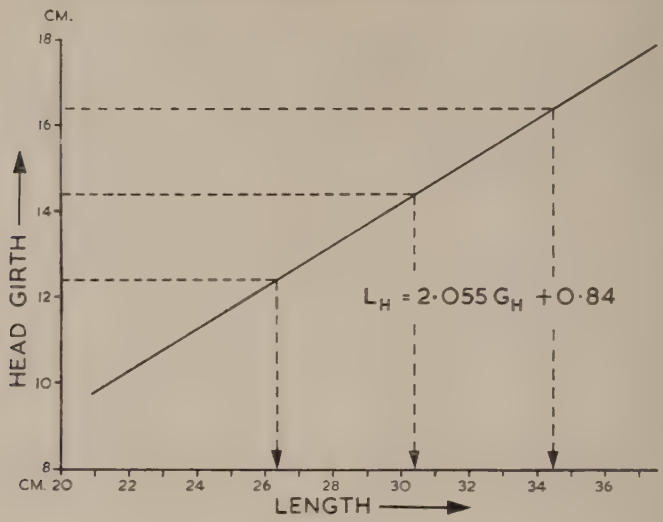

Figure 8. Showing the maximum 50 per cent. release lengths for 60 mm., 70 mm., and 80 mm. cod-end meshes as obtained from the regression of length on head-girth for haddock caught in May 1953.

Substituting $G_W = 12{\cdot}2$ cm. in (3) we get $L_W = 29{\cdot}0$ cm., which is 3·5 cm. higher than the haddock 50 per cent. release length.

The corresponding regression of L_H on G_H was:—

$$L_H = 2{\cdot}055\,G_H + 0{\cdot}84 \qquad (4)$$

and is shown in Figure 8. Equation (4) can be used to give the expected length of a haddock which would just pass through a completely flexible mesh. Now for an 80 mm. net the internal circumference of such a hypothetical mesh would be approximately 16·4 cm. and the expected length of a haddock of head-girth 16·4 cm. is, from equation (4), 34·5 cm.

It can be seen from Figure 5 of the text that this value just lies within the range of observed values for the 80 mm. seine, but that it is much higher than the trawl values. This corroborates the independent evidence that the cod-end meshes of the seine are more flexible during operation than the trawl cod-end meshes.

3. The second sample to be dealt with here consisted of measurements on 300 haddock and 41 whiting caught in an area north-east of the Firth of Forth during October 1953. The length range of haddock was 20 to 41 cm. while that of whiting was 21 to 45 cm.

The regressions of head-girth on length for the two species were again linear with indistinguishable slopes. The two fitted regressions were:—

$$G_H = 0{\cdot}354\,L_H + 2{\cdot}87 \qquad (5)$$
$$G_W = 0{\cdot}354\,L_W + 0{\cdot}81 \qquad (6)$$

That is, the average head-girth of haddock was 2·1 cm. greater than the average head-girth of whiting at any given length.

The regression of L_W on G_W for this set of data was found to be:—

$$L_W = 2{\cdot}624\, G_W - 0{\cdot}19 \qquad (7)$$

4. The third sample was collected during October 1953, off the north-east coast of Scotland. In all, 75 haddock of lengths ranging from 22 cm. to 37 cm. and 100 whiting of lengths ranging from 22 cm. to 32 cm. were measured.

For this set of measurements the regressions of head-girth on length were linear but there was a significant difference between the slopes of the lines. The equations of the fitted lines were:—

$$G_H = 0{\cdot}477\, L_H - 0{\cdot}73 \qquad (8)$$
$$G_W = 0{\cdot}402\, L_W + 0{\cdot}35 \qquad (9)$$

Again, over the range of lengths analysed the head-girth for haddock was found to be greater than the corresponding head-girth of whiting, the difference increasing with length. The excess of haddock head-girth over that of whiting in this sample lay between 0·6 and 1·3 cm.

The regression of L_W on G_W for the data was:—

$$L_W = 2{\cdot}156\, G_W + 2{\cdot}57 \qquad (10)$$

5. The above regressions were used to calculate expected 50 per cent. release lengths for whiting for both trawl and seine nets based on the best estimates available of the 50 per cent release length for haddock. Results derived in this way from the different samples were averaged and the mean values obtained are given in Table 5 together with the range of observed whiting 50 per cent. release lengths calculated from the present seine-net data and from earlier trawl experiments.

It will be seen that the average expected 50 per cent. release lengths for whiting fall near the upper limits of the ranges of observed values. This is to be expected, since other factors also play a part in determining the release of fish through a mesh.

6. Although the regressions of head-girth on length given here differ from sample to sample all three sets of data indicate the existence of a real difference between the head-girths of haddock and whiting at any

Table 5. Estimated and observed 50 per cent. release lengths for whiting.

Mesh Size (mm.)	Net	Haddock 50 % length (cm.)	Estimated whiting 50 % length (cm.)	Range of observed values (cm.)
60	Trawl	20·0	24	—
	Seine	22·0	26	22—25
70	Trawl	22·5	26	22—25
	Seine	27·5	31	28—31
80	Trawl	25·5	29	27—30
	Seine	34·0	37	34—37

given length over the ranges studied. Such a difference points almost inevitably to the conclusion that whiting escape more easily through the meshes of a net. In particular we may reasonably conclude that the 50 per cent. release length of whiting for either a trawl or a seine net is higher than that for haddock.

An explanation of the observed differences between the head-girth length relationship from sample to sample must await further investigation.

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A Note on Published Trawler/Seiner Comparisons.

By

M. Graham, R. J. H. Beverton, A. R. Margetts, and **J. A. Gulland,**

Fisheries Laboratory, Lowestoft.

THERE is published evidence that a seine with a 70 mm. mesh or thereabouts takes from a stock of **plaice** approximately the same sized fish as a trawler with a mesh 10 mm. greater. Four workers have described trials, one of them giving two sets. Taken by itself the evidence of any one trial would hardly be conclusive, and they vary in the meshes used and in the nature of the trials, but taken together they provide a convincing argument that the difference of about 10 mm. is real. How far it is due to different actions of fish or mesh in the two gears, or how far it can be explained on M a r g e t t s' s theory (1949) of preselection by seine warps, cannot be determined from published data. Throughout this note the selection effect of both gears will be considered as a whole, because in the published work there are no data from which the selection in the cod-end as distinct from selection in or by other parts of the gear can be determined.

For **dabs** there are only two sets of trials, but these show a difference in the same direction.

For **haddock** there is only one set, which also shows a difference in the same direction.

The difference for plaice seems certain. Those for dab and haddock, so far as published evidence goes, can be classed as only probable.

In presenting the evidence, it is first necessary to decide on some index of the run of sizes of fish caught by each gear. The mean or average size would be affected rather much by a few extremely large or extremely small fish that might happen by chance to be taken in one gear or the other. The mode, or most common size, is unduly

affected by what sizes of fish happen to be on the ground. The best index — not that it is entirely free from the faults mentioned — seems to be the half-way length, or "median" as it is called in statistical studies. Half the fish in the catch are bigger than the median size and half smaller. It will be realized that, as indeed with mean or mode, an apparently small difference in the position of the half-way point, e.g., 1 cm., reflects a considerable difference in the whole length-distribution.

We must also consider how selection should be described, seeking for a single figure to express the selective properties of each net that was tried. Buchanan-Wollaston's theory of mesh selection (1927), which seems to give a fair and practical account of what happens, was based on the following considerations. Some fish will be altogether too big to go through the mesh of a cod-end in which they find themselves, and these will have no chance of escaping. At the other extreme, there are fish that are so small that they can hardly fail to get through the mesh and escape. They have a 100 % chance of getting through. At some intermediate length of fish there is an even chance, say fifty-fifty, that a fish of that size will escape. This length is called the "50 % point", and has proved a useful measure of the selective action of a net.

Throughout this note the mesh is considered to have been measured by a gauge 2 mm. thick, narrower at one end than the other, inserted within the lumen of the mesh, and the figure given is the breadth of the gauge in millimetres as read when the progress of the gauge through the mesh is stopped, without force being used to push it further. All measurements are assumed to have been taken when the net was wet and in use.

A large number of experiments with trawl cod-ends have all indicated that as might reasonably be expected, there is, for each species of fish, a direct relationship between the size of mesh opening and the 50 % point of the size of fish escaping or retained by that mesh. Whether or not a fish will escape through a certain size of mesh will depend largely on the girth of the fish, and as the girth of the fish is directly proportional to the length of the fish, then the length of fish at the 50 % point will be directly proportional to the mesh size. For plaice, it has been found that in trawl cod-ends the length of fish at the 50 % point is 2·2 times the mesh-size, while for haddock the similar proportionality factor is from 3·0 to 3·3.

The first worker to investigate the mesh selection of seine-nets was Bowman (1928). His fishing in the Moray Firth in 1921 gave the interesting result that the Danish fishermen were catching haddock in their seines with a median about 9 cm. higher than that being found in the research vessel's trawl catches close by. As mesh measurements are not given in Bowman's paper, it is not possible to make any use of these data in the present review. Two years later, in 1923, and again in 1924, Bowman fished trawl against seine-net in St. Andrew's Bay, and measured the meshes. The species in these trials was plaice. The

trials confirmed each other, in that, with meshes not very different, the seine gave a median higher by just over 1 cm.

Clark (1934) determined the population of plaice on the ground by fishing with a trawl covered with shrimp netting, and then fished seine-nets of various mesh on the same ground. These trials did not yield usable data for our present purpose, but it is worth noting that his 50 % point for the 90 mm. seine on plaice appears to be near 20·5 cm., which is little greater, if at all, than the 50 % point that would be obtained with a trawl of the same mesh, according to our present appreciation of all published and unpublished data on selection in trawls. Clark's results did not show any reason for doubting the validity of the difference of 1 cm. or so discovered by Bowman.

Table 1.

Fish / Source	Number of Hauls Compared		A	B	C	D	E	F
	Trawl	Seine	Trawl Mesh (mm.)	Seine Mesh (mm.)	A—B (mm.)	Trawl Median (cm.)	Seine Median (cm.)	D—E (cm.)
Plaice								
Bowman, 1923	?	?	86	80	+6	22·1	23·4	—1·3
Bowman, 1924	?	?	80	80	0	23·1	24·2	—1·1
Margetts								
"Platessa"—"Primula"	3	4	79	99	—20	30·5	28·5	+2·0
"Platessa"—"Arabis"	7	6	97	97	0	31·2	34·5	—3·3
"Platessa"—"Arabis"	13	14	97	105	—8	30·9	33·1	—2·2
"Sir Lancelot"—"Arabis"	7	6	100	97	+3	31·3	34·5	—3·2
"Sir Lancelot"—"Arabis"	13	14	100	105	—5	31·9	33·1	—1·2
Dab								
Margetts								
"Platessa"—"Primula"	3	2	79	99	—20	19·3	22·2	—2·9
"Platessa"—"Arabis"	7	3	97	97	0	22·7	25·5	—2·8
"Platessa"—"Arabis"	13	12	97	105	—8	22·7	26·7	—4·0
"Sir Lancelot"—"Arabis"	3	3	100	97	+3	22·6	25·5	—2·9
Haddock								
Bowman, 1921	?	?	?	?	?	26·6	35·8	—9·2
Margetts								
"Platessa"—"Primula"	3	4	82	67	+15	29·7	29·1	+0·6

Jensen (1949) gave no data, and was not very happy about his experiments, but he thought the 50 % point for plaice to be 17·5 cm. for a 70 mm. seine-net. This would be roughly in keeping with Bowman's results, because the corresponding 50 % point for a trawl with 70 mm. mesh is 15·5 cm.

Margetts (1949) carried out trials with the seiner "Arabis", against which he fished the "Sir Lancelot" and the "Platessa", all three using meshes not very far from the 100 mm. His two trawlers used respectively 97 mm. and 100 mm. cod-ends while the seiner used both

a 97 mm. and 105 mm. cod-end. The trawlers' medians for plaice were both 3 cm. below the seiner's 97 mm. median, but were only 1—2 cm. below the seiner's 105 mm. median; the seiner's median dropped by just over 1 cm. with the change in mesh from 97 to 105 mm. while the trawlers' medians with unchanged meshes remained approximately the same. For dabs the difference in medians was greater, at about 3 cm., increasing to 4 cm. with the increase in seiner's mesh-size.

Margetts also reported fishing the seiner "Primula" against the "Platessa". The mesh of the "Primula's" plaice seine was 99 mm. on the average, while that in the "Platessa's" trawl was 79 mm. The few hauls in this experiment render the data suspect, but despite the seiner's considerably larger mesh the median of its plaice catch was found to be 2 cm. below the trawler's. For dabs the seiner's median was nearly 3 cm. higher than the trawler's.

Margetts also reported the medians for haddock in the same trial with the seiner using an intermediate seine with 67 mm. cod-end meshes and the trawler using 82 mm. cod-end meshes. That of the trawler was 0·6 cm. higher than that of the "Primula", which suggests that in so far as one can say anything from a single trial, the 15 mm. difference of cod-end mesh between the two gears was just more than enough to compensate for the different selective actions of the gears.

Of the work reviewed, Bowman's and Margetts's gives usable data. These are set out in Table 1, of which columns C and F may be compared. It is seen that when the meshes of the two gears did not differ very much, the trawler always caught a smaller run of plaice and dabs. The larger meshed trawler's haddock were only slightly bigger than the seiner's.

The data appear to provide evidence for a firm conclusion that there is an overall difference in the selective effect of the two gears, with the seine liberating relatively larger fish than does the trawl.

A second conclusion is that, measured by medians, this difference amounts to from 1 to 3 cm. in length of plaice. In a trawl, a change greater than the minimum one of 7 mm. in the cod-end mesh would be required to shift the median of the plaice catch 1·5 cm. As it is impracticable to be very precise in this matter, there seems to be a reasonably well established difference between the selective action of the two gears amounting to about 10 mm. in the mesh.

The results on dabs and haddock are too meagre for numerical estimates to be made of the differences in the selective effect on these two species, but when they are considered along with the results on plaice, there seems no doubt that there are selective effects in these species also, in the same direction as that in plaice, but of magnitude as yet unknown.

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The Length-Girth Relationships in Haddock and Whiting and their Application to Mesh Selection.

By

A. R. Margetts,

Fisheries Laboratory, Lowestoft.

Length-girth data.

The lengths and girths of freshly caught ungutted North Sea haddock and whiting were measured at sea in July, at all times between dawn and dusk. The fish were trawled and the total numbers measured, 690 haddock and 206 whiting, were taken as follows:— 266 haddock and 203 whiting from 20 fms. near the Tail End of the Dogger Bank, and 424 haddock and 3 whiting from various more northerly grounds ranging in depth between 34 and 40 fms. in the locality of the Great Fisher Bank, Devil's Hole, Little Fisher Bank, and English Klondyke.

The lengths were measured with the tails of the fish smoothed out to give maximum overall length and were measured to the centimetre below. The girths were measured with a tape measure in the form of a noose; they were measured to the nearest $^1/_4$ inch with the noose just closely around but not constricting the middle part of the fish where its girth was greatest; this girth will be referred to as the natural girth.

When measuring some of the fish, after the lengths and natural girths had been measured, the measuring noose was pulled just so tight that the bodies of the fish were constricted to such an extent that the whole fish could, when gently pulled, only just pass through. This constricted girth was then measured. It was found that the constricted girth, which was never less than the head girth, was less than the natural girth by $^1/_4$ inch at 30 cm., $^1/_2$ inch at 35—40 cm. and $^1/_2$—$^3/_4$ inch at 46 cm. length of fish. The mean natural girth of haddock at each centimetre length as measured is shown in Table 1 and the corresponding figures for whiting are shown in Table 2.

Table 1. Haddock length and girth measurements.

Length cm.	Number of fish measured	Mean natural girth cm.	Constriction cm.	Smallest recorded natural girth cm.
21	4	11·4	—	10·8
22	17	11·4	—	10·8
23	27	12·0	—	10·2
24	56	12·4	—	11·4
25	68	12·9	—	11·4
26	66	13·4	—	12·1
27	52	14·1	—	13·3
28	20	14·6	—	13·3
29	16	15·2	—	14·0
30	28	15·7	0·6	14·6
31	30	16·2	—	15·2
32	40	16·8	—	15·2
33	41	17·4	—	15·9
34	35	18·0	—	16·5
35	29	18·5	1·3	16·5
36	24	19·2	1·3	17·1
37	16	20·0	1·3	18·4
38	14	20·0	1·3	19·0
39	14	20·6	1·3	17·1
40	15	21·3	1·3	19·7
41	10	22·0	1·3	21·0
42	14	22·7	—	21·6
43	12	23·4	—	22·2
44	11	23·4	—	21·6
45	3	24·1	—	22·2
46	11	24·8	1·3—1·9	22·9
47	4	25·9	—	25·4
48	2	26·7	—	—
49	3	26·5	—	—
50	1	29·2	2·5	—
51	1	27·3	—	—
52	2	28·9	—	—
53	3	28·6	—	—
63	1	37·5	—	—

The haddock dimensions are plotted in Figure 1. Curve 1 shows the relationship between length and mean natural girth at each centimetre length; it has been fitted by eye to points from Table 1 and has been drawn as a straight line, since the relationship over the range considered (21—53 cm.) is apparently linear with very little scatter of points away from the line. The slope of the line drawn is actually best described by the equation Length = (Natural Girth × 1·75) + 2·7 cm. This linear relationship is very close to proportionality. In fact, over the range of lengths 20—40 cm., an assumed proportionality with factor 1·9 can be conveniently used for most practical purposes. The regression line of length on girth, as fitted by the method of least squares, is Length = (Natural Girth × 1·69) + 3·9 cm. Curve 2, relating length

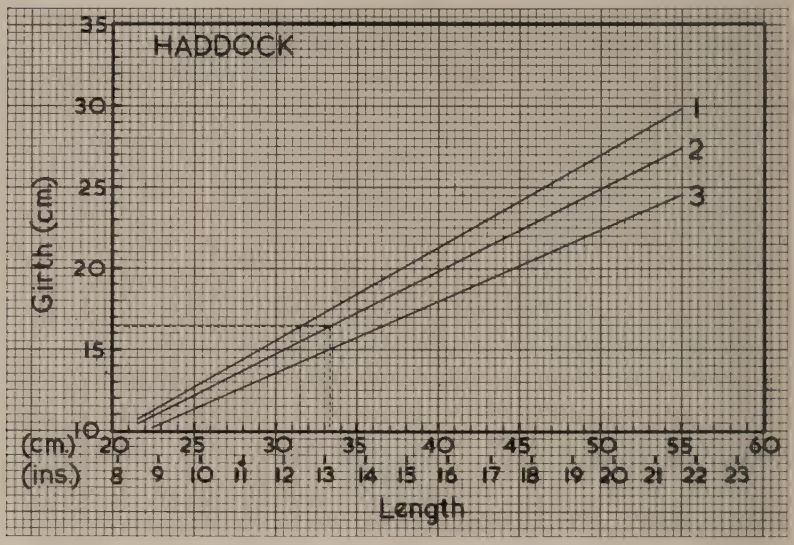

Figure 1. Length-girth relationship of haddock.
1. Natural girth of average-condition fish.
2. Constricted girth of average-condition fish.
3. Constricted girth of thin fish.

and constricted girths of average-condition fish, shows the average size of fish just squeezed through a noose of any particular size. Curve 3 shows the lengths of thin haddock that can just be squeezed through nooses of particular sizes; it was compiled by estimating the constricted girth of the fish with smallest natural girth at each centimetre length.

The whiting dimensions are plotted in Figure 2. Curve 1 relates length to natural girth. As in the case of haddock, the length-girth relationship over the range investigated (17—43 cm.) is considered as linear and the line drawn is fitted by eye; in this case it is described by the equation Length = (Natural Girth × 1·84) + 3·2 cm. For convenience of working a proportionality factor of 2·1 is indicated. The regression line of length on girth, as fitted by the method of least squares, is Length = (Natural Girth × 1·46) + 9·6 cm., but it should be noted that most of the points lie within the comparatively narrow range of length 28—34 cm. The only observations made on the constriction of whiting were that the difference between natural girth and constricted girth was greater in a whiting than in a haddock of the same length; over the range of length 30—35 cm. the constricted girth of whiting (defined as for haddock above) was found to be about half an inch (13 mm.) less than the natural girth. Curve 2 relates length and constricted girth of average-condition fish and curve 3 the length and constricted girth of the thinnest fish encountered in each centimetre length-group.

Discussion and conclusions.

Information about the length-girth relationship of any fish is useful both as a first check on the plausibility of mesh-selection experiment results and as a basis for estimating the selectivity of other meshes, once that of a particular size of mesh is known.

In estimating the upper limit of the 50 % selection point of a particular mesh-size from a purely physical basis the flexible noose used to measure fish girths can be considered as a completely flexible mesh.

Table 2. Whiting length and girth measurements.

Length cm.	Number of Fish measured	Mean natural girth cm.	Constriction cm.	Smallest recorded natural girth cm.
17	1	9·5	—	—
18	—	—	—	—
19	1	9·5	—	—
20	—	—	—	—
21	1	9·5	—	—
22	—	—	—	—
23	1	11·4	—	—
24	1	11·4	—	—
25	1	12·7	—	—
26	7	12·0	—	10·8
27	7	12·9	—	11·4
28	9	13·2	—	12·1
29	18	13·4	—	12·1
30	20	14·0	1·3	12·7
31	25	15·1	1·3	13·3
32	23	15·8	1·3	14·0
33	25	16·3	1·3	14·6
34	20	17·0	1·3	14·6
35	10	17·0	1·3	16·5
36	15	18·3	—	16·5
37	5	18·7	—	17·1
38	1	20·3	—	—
39	5	19·8	—	19·0
40	2	20·6	—	—
41	4	20·8	—	19·7
42	3	19·7	—	19·0
43	1	21·0	—	—

Conclusions such as those in the following example concerning haddock and an 80 mm. meshed net can then be reached.

The internal circumference of an 80 mm. mesh, as measured by a gauge 2 mm. thick, will be 164 mm. From Figure 1, curve 1, the length of haddock with average natural girth of 164 mm. is 31·5 cm. But from Figure 1, curve 2, it is apparent that a haddock of average length 33·5 cm. can squeeze through a flexible noose of circumference 164 mm. The longest haddock that can just squeeze through a flexible noose of

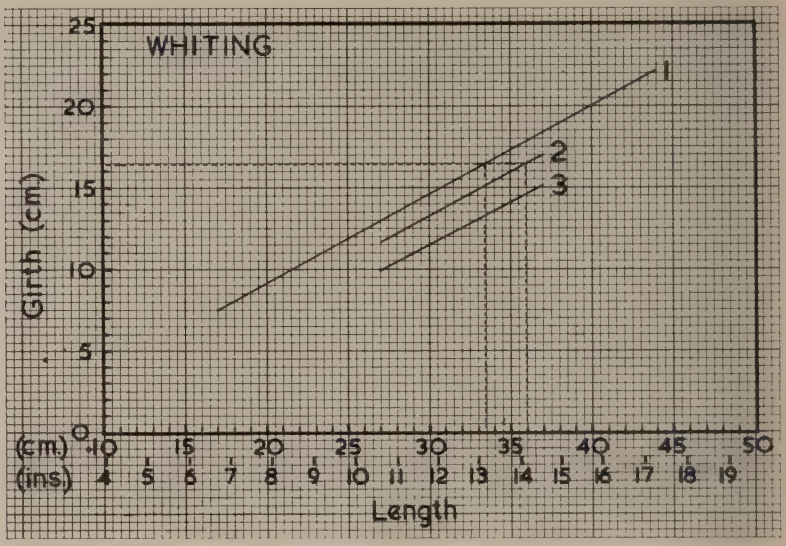

Figure 2. Length-girth relationship of whiting.
1. Natural girth of average-condition fish.
2. Constricted girth of average-condition fish.
3. Constricted girth of thin fish.

circumference 164 mm. (i.e., the thinnest at that length) is, from Figure 1, curve 3, 36·4 cm. long.

In a double sisal or manila cod-end the variation in size between meshes usually ranges over 10 mm., i.e., 5 mm. either side of the mean mesh-size. Thus the largest mesh in an 80 mm. cod-end would be about 85 mm., or of internal circumference 174 mm. By reference to Figure 1, curves 2 and 3, it is seen that an average haddock of length 35·5 cm. or a very thin 39 cm. haddock can just squeeze through a flexible noose of internal circumference 174 mm.

From the foregoing it can be said that, assuming the meshes in a cod-end to be completely flexible: —

(a) the thinnest haddock that could find and just squeeze through the largest mesh in an 80 mm. cod-end would most probably be no longer than 39 cm.; this, on a theoretical 80 mm. mesh-selection ogive, would represent a point near the 100 % retained limit.

(b) the longest average-condition haddock that could find and squeeze through the largest mesh in an 80 mm. cod-end would be about 35·5 cm.

(c) the length of average-condition haddock that could just squeeze through the average mesh in an 80 mm. cod-end would be

33·5 cm.; this, on the 80 mm. mesh-selection ogive, would represent a point very near to the 50 % point.

(d) the length of average-condition haddock that could pass comfortably through the average mesh in an 80 mm. cod-end would be 31·5 cm.; this, on a selection ogive, would represent a point between the 50 % and 0 retained points.

It is usual for 50 % selection points, when quoted, to refer to the average mesh-size of the net and the average size and condition of fish. The 50 % point of the 80 mm. completely flexible mesh would for haddock probably be somewhere between the above latter two lengths (c) and (d), 33·5 cm. and 31·5 cm., being slightly below the greater length of 33·5 cm. partly on account of some fish not having time to complete their escape.

Similarly for whiting, by reference to Figure 2, curves 1 and 2, the 50 % selection length of a completely flexible 80 mm. mesh would be expected to lie between 33·5 and 36 cm. Thus, from consideration of some of the practical features of mesh selection, and on the assumption that meshes are completely flexible, for any one mesh-size the 50 % selection point might reasonably be expected to be in the order of 7—9 % greater for whiting than for haddock.

If the 50 % point for haddock of the 80 mm. completely flexible mesh estimated in this way is taken as 32·5 cm. then the proportionality factor relating mesh-size to fish length at the 50 % point is 4·06. The figure for such a factor derived by Beverton and Holt from trawl mesh experiments, and confirmed by recent work on trawls in the United States, is 3·3. Much of the difference between the two figures must be due to there being no such thing as a completely flexible cod-end mesh conforming exactly to the girth shape of escaping fish; trawl cod-end meshes of the size used are a rather rigid, diamond shape when in action. The figure for the 50 % selection-point/mesh-size factor for any 80 mm. netting more flexible than double sisal or manila trawl cod-ends would, for haddock, be expected to be between the limits 3·3 and 4·0.

Trials of Mesh Selection in Trawls and Seines.

By

Michael Graham,

Fisheries Laboratory, Lowestoft.

ORIGINALLY, Scottish workers in the research vessel "Kathleen" found release of haddock by seines that seemed abnormally high compared with that of trawls of the same cod-end mesh. When further Scottish evidence supported the original discovery, it was evident that the International Council should be informed, and that the facts should be firmly established and brought to the attention of the Permanent Commission of the Overfishing Convention of 1946. It was therefore necessary quickly to obtain a body of evidence on the authenticity and magnitude of the difference in selectivity of trawls and seines. The design of the trials made by English vessels fell to R. J. H. Beverton and the present writer, and the latter directed the work and reported on it. The naturalists-in-charge at sea were A. R. Margetts and J. A. Gulland, both of whom also participated in the voyage-to-voyage planning, and helped to write this paper. Margetts had already in hand the girth measurements of haddock that formed, in the end, the means of generalizing the observations on selection made at sea (cf. Jensen, 1949); the writer would commend the method (when girths are measured sensitively, as Margetts did) as possibly in the future taking the place of the uncertain judgement hitherto used in generalizing from selection ogives. A collection of selection ogives usually varies in the parameters to a troublesome degree, doubtless owing to both random and systematic errors (Davis, 1934). It is evident that the writer is greatly in debt to the colleagues named, and to others who altered their plans at short notice.

In August 1953 the "Scanlord" of Grimsby used alternately seine-nets of 73 and 82 mm. mesh respectively, these being the average meshes in the cod-end of each net (Table 1). It is seen in Figure 1 and Table 2 that the catches of the larger meshed net become 50 % of the smaller meshed net at approximately 35 cm. length. This will be taken as an

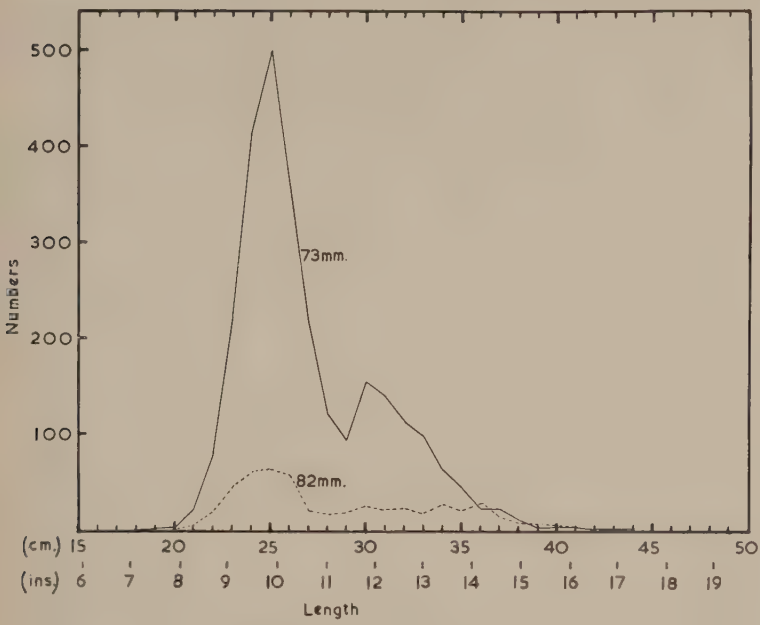

Figure 1. Numbers of haddock caught by 73 mm. seine-net and 82 mm. seine-net (10 hauls with each net).

approximation of the "50 % point" as defined by G r a h a m *et al.* (this number, p. 52). Two errors are involved, and these would act in opposite directions: had the two nets been fishing equally well, the true point would be above that shown by this comparison, because some 35 cm. fish doubtless escaped even the 73 mm. net; but this would be compensated at any rate partly. It was discovered at the end of the voyage that the 82 mm. net was set up rather more tightly than the 73 mm. net, which would be expected to reduce its efficiency a little, so that it ought to have caught a few more fish of 35 cm. length to balance those few presumed to have escaped from the 73 mm. mesh (see Table 3).

Table 1. Cod-end mesh-sizes (mm.).

Ship	Gear	Mesh-sizes					Average
"Scanlord"	Large meshed seine	81·0	81·3	82·9	—	—	81·7
"Scanlord"	Small meshed seine	71·8	73·3	73·5	72·9	74·7	73·2
"Sir Lancelot"	Trawl	75·2	76·6	74·8	—	—	75·5
"E. Crawford"	Large meshed seine	80·4	81·6	81·3	81·4	—	81·2
"E. Crawford"	Small meshed seine	72·3	72·0	—	—	—	72·1
"Platessa"	Large meshed trawl	79·05	78·45	78·85	78·15	—	78·6
"Platessa"	Small meshed trawl	90·1	89·05	90·05	89·3	—	89·6

Table 2. Length frequency of haddock in 10 paired hauls of M. S. "Scanlord" in the Moray Firth, August 1953.

	73 mm. mesh cod-end										
Haul	16	19	23	26	28	30	32	38	40	42	Total
Depth (fms.)	33	38	34	33	34	35	35	37	37	40	
Length (cm.)											
19	1	—	—	—	—	—	—	—	—	—	1
20	—	—	1	1	—	—	—	1	—	—	3
21	2	—	4	4	—	9	1	1	—	1	22
22	19	2	9	2	1	21	3	7	2	14	80
23	50	3	43	17	3	59	11	9	1	25	221
24	114	3	60	23	2	134	21	14	7	36	414
25	129	3	82	24	4	153	35	8	7	54	499
26	78	5	63	21	1	128	22	8	7	27	360
27	55	1	36	15	—	75	8	2	4	18	214
28	39	—	16	12	—	40	4	—	3	7	121
29	31	—	6	11	—	40	3	—	1	2	94
30	57	2	14	12	1	49	10	3	2	4	154
31	46	3	19	12	1	39	9	2	6	3	140
32	31	3	19	12	—	32	7	1	3	5	113
33	31	1	15	6	—	27	3	1	6	8	98
34	9	—	5	9	—	10	3	14	6	7	63
35	13	1	5	3	—	13	1	4	3	1	44
36	5	—	3	3	—	2	1	4	1	3	22
37	3	—	1	3	—	4	—	3	3	5	22
38	3	—	—	1	—	2	—	1	—	3	10
39	—	—	—	1	—	1	—	—	—	—	2
40	—	—	—	2	—	—	—	—	1	—	3
41	—	—	—	2	—	—	—	1	—	—	3
42	1	—	—	—	—	—	—	—	—	—	1
43	—	—	—	—	—	1	—	—	—	—	1
44	1	—	—	—	—	—	—	—	—	—	1
45	—	—	—	—	—	—	—	—	—	—	—
46	—	—	—	—	—	—	—	1	—	—	1
47	—	—	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—	—	—
Total	718	27	401	196	13	839	142	85	63	223	2,707
Median											26·3 cm.

By reference to M a r g e t t s's paper on length-girth relationships (this number, p. 58) it can be seen in Figure 1 that 34·4 cm. is approximately the length lying on curve 2 at the level of 168 mm. girth, which is the internal measurement of an 82 mm. net. When we consider how lively the fish are in a seiner's catch, it seems reasonable that they should have a 50 % chance of getting through at the degree of constriction represented by curve 2, obtained as described by M a r g e t t s.

Table 2 continued.

82 mm. mesh cod-end

Haul	17	20	24	25	27	29	31	39	41	44	Total
Depth (fms.)	32	41	32	32	34	35	35	36	37	40	
Length (cm.)											
19	—	—	—	—	—	—	—	—	—	—	—
20	—	—	1	—	—	—	—	—	—	—	1
21	1	—	2	—	—	—	2	—	—	—	5
22	8	—	2	3	—	2	2	1	—	—	18
23	21	—	5	5	—	1	6	5	1	2	46
24	26	—	13	9	3	1	4	3	2	—	61
25	28	—	16	5	1	4	5	2	1	2	64
26	27	—	21	3	—	2	1	3	—	1	58
27	5	—	8	3	—	—	—	4	1	—	21
28	4	—	5	1	1	—	1	2	1	1	16
29	5	—	6	3	1	2	1	—	—	—	18
30	4	1	8	4	—	1	2	2	1	2	25
31	1	—	11	4	—	1	—	3	1	1	22
32	5	—	10	1	—	—	1	4	2	—	23
33	1	—	10	1	—	—	—	4	1	1	18
34	—	—	14	1	1	—	—	6	2	3	27
35	2	—	5	—	—	—	—	6	3	5	21
36	1	—	7	—	—	1	—	10	1	7	27
37	—	—	2	—	—	—	—	6	3	3	14
38	—	—	1	—	—	—	—	4	1	2	8
39	1	—	2	—	—	—	—	1	1	2	7
40	1	—	1	1	—	—	—	2	—	—	5
41	1	—	—	—	—	—	—	—	2	—	3
42	—	—	2	—	—	—	—	—	—	—	2
43	—	—	—	—	—	—	—	—	—	—	—
44	—	—	1	—	—	—	—	—	—	—	1
45	—	—	—	—	—	—	—	—	—	—	—
46	—	—	—	—	—	—	—	—	—	—	—
47	—	—	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	—	—	—	—	—
50	—	—	—	—	—	—	—	—	—	—	—
Total	142	1	153	44	7	15	25	68	24	32	511
Median											27·1 cm.

If it is accepted that the "Scanlord's" comparison fits Margetts's curve 2, the comparable 50 % point of an 80 mm. mesh will be approximately 33 cm. This is substantially above that for the trawl, i.e., a 50 % point of 26 cm. (Beverton and Holt's analysis of Davis's data, in press). The differences of 28 % in length and 104 % in gutted weight are striking. Returning to Margetts's curve 2, we can find that a 26 cm. haddock would appear to fit a seine mesh

Table 3. Setting up of seine nets — M. S. "Scanlord".

In this table the tightness with which the net was found to be stapled on to the ropes after shrinkage and use is expressed as the average number of fully stretched meshes between adjacent staplings. (Two fully stretched meshes between staplings indicates that the netting is tight and no "flow" is allowed.)

	82 mm. net		73 mm. net	
	Headline	Groundrope	Headline	Groundrope
Wings	1·84	1·81	1·79	1·75
Shoulders	1·97	1·92	1·72	1·62

of 125 mm., internal measurement, that is, a 60 mm. mesh. This, however, assumes that the smaller fish would be as strong as the larger, which one would not expect.

The results of directly comparing the length frequencies taken by the seiner "Scanlord" and the trawler "Sir Lancelot", fishing as near to each other as they could, are given in Table 4, which includes comparable hauls in which the mesh used by the "Scanlord" was 73 mm. and that used by the "Sir Lancelot" 75 mm. It is to be observed that the seiner

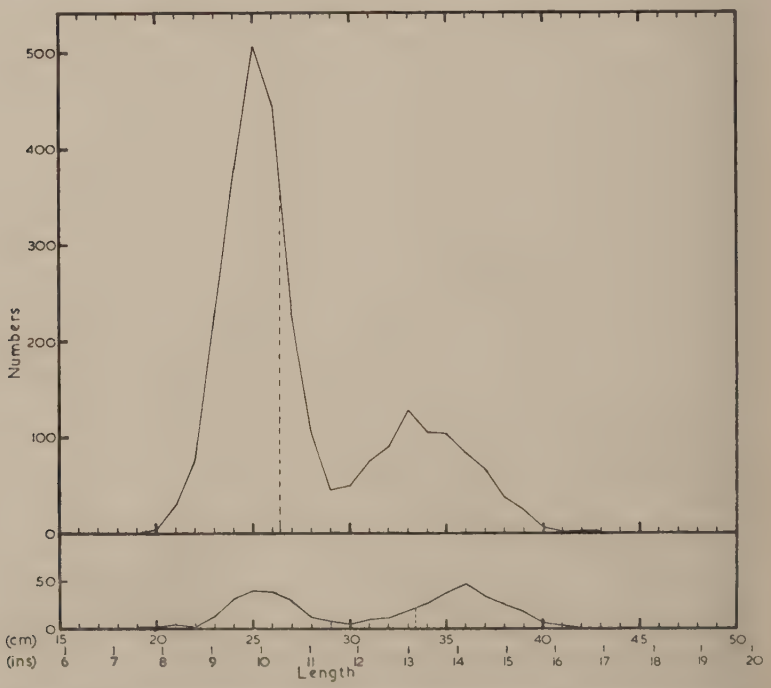

Figure 2. Numbers of haddock caught by 72 mm. seine-net (above) and 81 mm. seine-net (below) — 8 hauls with each net . Median shown by dotted line.

Table 4. Catches of haddock by seiner using 73 mm. mesh and trawler using 75 mm. mesh, Moray Firth, August 1953.

Length cm.	Seiner "Scanlord" Hauls 10, 12, 14, 16, 19, 21, 23, 26, 28, 30, 32	Trawler "Sir Lancelot" Hauls 5-11, 18-29	Length cm.	Seiner "Scanlord" Hauls 10, 12, 14, 16, 19, 21, 23, 26, 28, 30, 32	Trawler "Sir Lancelot" Hauls 5-11, 18-29
18	—	2	42	2	18
19	1	—	43	3	15
20	4	6	44	1	15
21	26	22	45	—	15
22	79	93	46	—	6
23	243	234	47	—	9
24	460	525	48	—	6
25	559	666	49	—	4
26	442	471	50	—	9
27	274	340	51	—	1
28	164	270	52	—	3
29	138	343	53	—	1
30	244	453	54	—	2
31	255	374	55	—	3
32	200	419	56	—	3
33	183	315	57	—	1
34	92	241	58	—	—
35	66	191	59	—	1
36	35	127	60	—	1
37	17	106	61	—	—
38	16	53	62	—	1
39	3	60	Total	3,518	5,482
40	7	40	Median	26·9 cm.	29·3 cm.
41	4	17			

caught altogether much fewer fish than the trawler, and that the deficiencies were mainly among the larger sizes of fish. Two processes may have contributed to the differences found. The crew of the "Scanlord" were strange to the practice of "fly-dragging", which is the typical method of operation when haddock fishing, and may thereby have lost larger fish disproportionately. The seine may also have taken very small fish disproportionately, because in the short period of a seine's operation, these might not have had the same opportunity to find the wall of net as they would have in the longer tow of a trawl. Owing to the possibility of the first of these two processes having operated in this trial, the data cannot fairly be considered as typical of haddock seining and will not be used further.

More reliable comparisons of trawler and seiner are available from part of the work of the "Elizabeth Crawford" and the "Platessa" during September 1953.

"Platessa" using 79 and 90 mm. trawls, fished against the "Elizabeth Crawford", of Berwick, using 72 and 81 mm. seines. The data for the first three days' work on two grounds, one 20 miles off Berwick in

Table 5. Length frequency of haddock in 8 paired hauls of M. S. "Elizabeth Crawford" in September 1953.

	72 mm. cod-end								
Haul	4	6	8	10	13	15	17	19	Total
Depth (fms.)	43	45	44	38	38	38	38	38	
Length (cm.)									
19	—	1	—	—	—	—	—	—	1
20	—	2	1	—	—	1	—	—	4
21	—	7	1	4	5	5	5	3	30
22	4	16	5	3	6	9	14	19	76
23	14	29	8	14	18	39	42	63	227
24	12	44	20	15	37	55	66	129	378
25	22	53	29	31	43	66	93	169	506
26	35	37	24	21	47	57	85	139	445
27	13	19	21	22	19	27	37	70	228
28	9	6	12	10	9	9	21	31	107
29	5	5	6	3	1	6	9	11	46
30	7	9	13	5	—	4	5	7	50
31	10	10	16	11	3	4	13	9	76
32	12	13	11	18	5	3	10	18	90
33	20	7	25	18	5	7	25	21	128
34	24	4	18	16	2	3	18	20	105
35	21	6	14	19	7	3	21	13	104
36	20	3	14	17	3	—	14	13	84
37	17	3	15	9	2	2	12	7	67
38	8	3	4	6	—	3	9	5	38
39	9	1	3	3	—	1	4	3	24
40	1	—	4	1	—	—	—	—	6
41	1	—	—	—	—	—	—	—	1
42	1	—	—	—	—	—	1	—	2
43	—	—	2	—	—	—	—	—	2
44	—	—	—	—	—	—	—	—	—
45	—	—	1	—	—	—	—	—	1
46	—	—	—	—	—	—	—	—	—
47	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	—	—	—
49	—	—	—	—	—	—	1	—	1
50	—	—	—	—	—	—	—	—	—
Total	265	278	267	246	212	304	505	750	2827
Median									26·4 cm.

43 fathoms and the other 6 miles off Berwick in 38 fathoms, are shown in Tables 5 and 6, and plotted in graphs in Figures 2 and 3.

The seiner data are for equal fishing time, the nets being fished alternately for eight pairs of hauls; they confirm sufficiently nearly the "Scanlord's" results on the 50 % selection point of the 81 mm. seine being in the region of 35 cm. length of haddock. (As in all comparative fishing work a proportion of hauls was abortive — damaged gear, etc.

Table 5 continued.

	81 mm. cod-end								
Haul	2	5	7	9	11	14	16	18	Total
Depth (fms.)	43	46	44	38	38	38	38	38	
Length (cm.)									
19	1	—	—	—	—	—	—	—	1
20	—	—	—	1	—	—	—	—	1
21	—	—	—	2	1	1	—	—	4
22	—	—	1	—	—	1	—	—	2
23	—	—	2	6	1	2	1	1	13
24	—	4	—	11	4	2	6	5	32
25	1	3	2	9	8	1	10	6	40
26	—	1	8	7	5	2	9	7	39
27	—	4	5	6	5	1	4	4	29
28	2	1	1	2	2	—	3	1	12
29	1	4	3	—	—	—	—	—	8
30	1	2	1	—	—	—	1	—	5
31	3	2	—	2	—	—	3	—	10
32	2	2	—	—	—	2	5	—	11
33	2	1	5	2	3	—	5	1	19
34	6	4	—	1	3	4	9	—	27
35	2	7	2	1	6	3	11	6	38
36	7	10	3	2	6	1	14	4	47
37	5	7	2	1	5	4	6	4	34
38	2	8	1	2	4	—	5	4	26
39	1	3	2	1	1	—	5	5	18
40	1	3	—	—	—	—	—	2	6
41	1	—	2	—	—	—	—	—	3
42	—	1	—	—	—	—	—	—	1
43	—	—	—	—	—	—	—	—	—
44	—	—	—	—	—	—	—	—	—
45	—	—	—	—	—	—	—	—	—
46	2	—	—	—	—	—	—	—	2
47	—	—	—	—	—	—	—	—	—
48	—	—	—	—	—	—	1	—	1
49	—	1	—	—	—	—	—	—	1
50	—	—	—	—	—	—	—	—	—
Total	40	68	40	56	54	24	98	50	430
Median									33·4 cm.

All of the "Scanlord's" and "Elizabeth Crawford's" hauls that could be used as comparable pairs have been used in making the relevant tables.)

The trawler's fishing was matched with the seiner's in order primarily that the length distributions of the haddock caught by the two trawls could be compared with those of the haddock caught by the two seines. The trawler data represent five hauls with the 79 mm. net and six hauls with the 90 mm. net made approximately alternately;

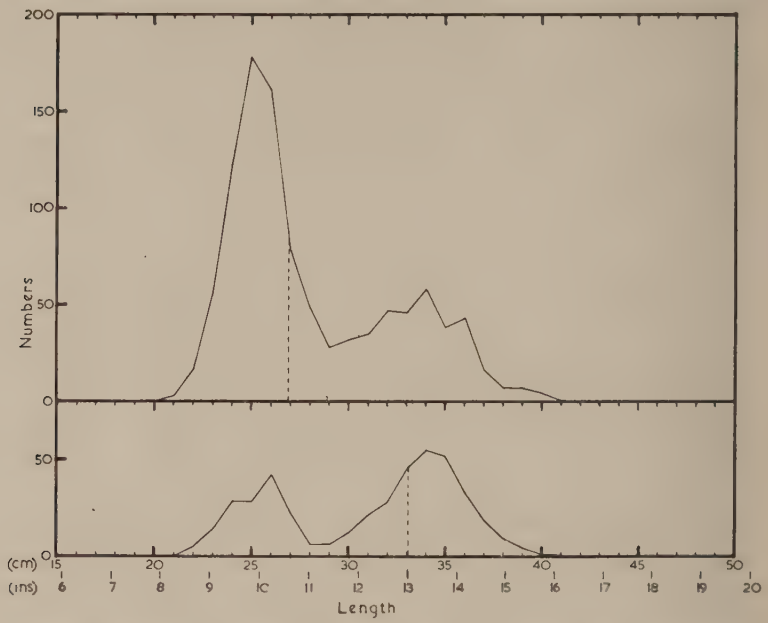

Figure 3. Numbers of haddock caught by 79 mm. trawl (above) and 90 mm. trawl (below). Median shown by dotted line.

they are thus only roughly comparable quantitatively between the two trawl mesh-sizes, but the apparent trawl mesh-selection level indicated is not out of keeping with the results of other work on trawls.

It may be noted that G r a h a m *et al.* (this number, p. 52) used the median as perhaps the fairest single index of length distribution in comparisons. The figures for the present series are:—

	Mesh	Median length of haddock
"Elizabeth Crawford", seine	72 mm.	26·4 cm.
"Platessa", trawl	79	26·9
"Elizabeth Crawford", seine	81	33·4
"Platessa", trawl	90	33·1

(Further data for work of this cruise are still to be reported on.)

These figures show close similarity between the sizes of haddock caught in a 72 mm. seine and a 79 mm. trawl, and also between those of haddock caught in an 81 mm. seine and 90 mm. trawl. Inspection of the graphs in Figures 2 and 3 gives the same impression. The new results therefore confirm the conclusion from the "Primula"/"Platessa" trial, which found for haddock about the same relation as has been shown for plaice:— that a seine catches a run of fish approximately the same as a trawl of mesh 10 mm. greater.

Table 6. Catches of haddock by trawler and seiner fishing on the same grounds, September 1953.

Length cm.	Seiner "Elizabeth Crawford"		Trawler "Platessa"	
	72 mm. mesh	81 mm. mesh	79 mm. mesh	90 mm. mesh
19	1	1	—	—
20	4	1	—	—
21	30	4	3	—
22	76	2	17	5
23	227	13	56	14
24	378	32	123	28
25	506	40	178	28
26	445	39	161	42
27	228	29	79	22
28	107	12	49	6
29	46	8	28	6
30	50	5	32	12
31	76	10	35	21
32	90	11	47	28
33	128	19	46	45
34	105	27	58	55
35	104	38	38	52
36	84	47	43	33
37	67	34	16	18
38	38	26	7	9
39	24	18	7	4
40	6	6	4	1
41	1	3	—	—
42	2	1	—	—
43	2	—	—	—
44	—	—	—	—
45	1	—	1	—
46	—	2	—	—
47	—	—	—	—
48	—	1	—	—
49	1	1	—	—
50	—	—	1	—
Total	2827	430	1029	429
Median	26·4 cm.	33·4 cm.	26·9 cm.	33·1 cm.

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A Subcutaneous Tag for Fish.

By

E. D. Le Cren,

Freshwater Biological Association, Ambleside, Westmorland.

Introduction.

Marking of fish is now a widely used tool in ecological studies, and a good method of marking each species being investigated is essential if adequate data are to be obtained on migrations, populations, and mortality rates. A fish mark should fulfil the following requirements:— (1) enable individual fish to be easily and unmistakably identified in the field; (2) be easy to put on the fish; (3) have no effect on health, growth, mortality, or behaviour; (4) remain on the fish for life; (5) render a marked fish easily recognizable by fishermen, but not predators; (6) be easily and inexpensively manufactured. No mark has yet been devised which is perfect in all these respects, and most marks fail to some extent, usually by their impermanence and their effect upon the fish carrying them. The above ideal requirements are usually best approached by some form of tag which can bear a serial number and be attached to some part of the fish. Where it is necessary to distinguish only a few groups of fish, as opposed to individuals, removal of one of the fins has been widely practised. It has also been discovered that a mark that is suitable for one species may prove unsatisfactory for another even quite closely related species.

Salmonid fishes have proved particularly difficult to mark. Silver tags have been attached by wire to the dorsal fin, and various metal tags to the jaws or operculum but, although in some instances recaptures of tagged fish have yielded the data required, in most cases these tags have proved rather unsatisfactory, mainly because they were sloughed off within a few months. Successful results have been obtained from the tagging of salmon (*Salmo salar* L.) with the Lea "hydrostatic" tag, but this is too large and expensive for smaller species. Recently Lindroth (1953) has used a body-cavity tag for salmon smolts.

Investigations into the biology of the char (*Salvelinus willughbii* Gunther) in Windermere (briefly described in Frost, 1951) revealed the need for a satisfactory method of marking these fish. After preliminary trials with various methods it was decided to use a metal tag placed just beneath the skin. In order to be sure of recognizing them in the field the tagged fish were also marked externally by clipping a

fin, and my colleagues Dr. C. H. Mortimer and Mr. W. H. Moore designed and built an electronic tag detector which was capable of finding a metal tag beneath the skin (Moore & Mortimer, 1954). Although the subcutaneous tag does not fulfil all the six requirements of the perfect tag outlined above, it has proved, in conjunction with a clipped fin, to be more satisfactory than any other method yet tried on the char and as it appears that truly subcutaneous tags may not have been used before (Rounsefell & Kask, 1945), it has been thought worth while to present this account of the method as developed and tested so far.[1]) The present paper describes the tag and the methods of marking char with it, and outlines some of the preliminary experiments with various types of mark. Finally the results of some small pond experiments and three years' field observations are analysed in an attempt to assess the success of the tag.

This method of marking was developed in close conjunction with the investigations into the general biology of the char being carried out by Dr. Winifred Frost. I am indebted to Dr. C. H. Mortimer and Mr. W. H. Moore for their development of the tag detector, and I am very grateful to Mr. E. Langman, and Mr. G. J. Thompson and his assistants for their help in carrying out the experiments described, and to Miss J. C. MacCormack for assistance in the analysis of the results.

Description of the Tag and Method of Marking.

The tag used is a flat slip of Monel metal 15 mm. by 4 mm. cut from metal 0·254 mm. (0·010 inch) thick. The ends are cut rounded so as to make the tag easier to insert and without sharp corners that might irritate the fish. Each tag is serially numbered with a six digit number, and it has been found convenient to have the tags packed in envelopes each containing 25 serial tags. For inserting the tag a finely pointed sharp scalpel is used. A small vertical slit as long as the width of the tag is made in the skin, and the skin then lifted from the flesh beneath for two or three millimetres in front of or behind the slit, with the point of the scalpel. The tag is then inserted and pushed between the skin and the muscles with a finger-nail. A final push with the scalpel point slides the end of the tag clear of the slit in the skin so that it is completely hidden. It is convenient for right-handed people to insert the tag forwards on the left-hand side and backwards on the right-hand side of the fish. It has been found that with a certain amount of practice the tag can be inserted quickly and successfully nearly every time. Occasionally too large a slit is made or the tag "dives" down into the muscles. The tags have so far been inserted in three different positions — anterior to, immediately beneath, and

[1]) Since this was written I have learnt that Dr. E. Bertelsen (Danmarks Fiskeri- og Havundersøgelser) has simultaneously and independently been marking plaice in the Limfjord and North Sea with a plastic subcutaneous tag (Bertelsen, MS and personal communication). I am indebted to Dr. Bertelsen for this information and permission to publish it.

posterior to the dorsal fin, in all cases dorsal to the lateral line. Different groups of marked fish can be distinguished by the position of the tag and whether it is on the left or right side.

In the fin-clipping operation the whole fin is removed near the base with a pair of scissors. In the 1950—51 season the anal fin was removed, and in the 1951—52 season one of the pelvic fins.

In the larger-scale field marking experiments the fish were caught mostly in seines, but in a few instances in gill nets. They were kept in baths, cans, or wire-netting traps till marked. During the marking operations a team of four was usually employed — one clipping the fins, one measuring and sexing, one tagging, and one recording.

On recapture the marked fish can be recognized by the fin clip, although considerable but not complete regeneration of the fin can take place. The scar of the tag-wound is nearly always visible on careful examination and the tag can usually be felt beneath the skin. A final check can be made with a tag-detector such as that designed by Moore and Mortimer (1954) specially for this purpose. A small slit can be cut again where the original slit was made, and the tag removed with fine forceps. After the number has been read the tag can be replaced under the skin and the fish released again. It would probably be possible, however, to examine the tag in this way only at intervals of several months.

Preliminary Experiments with various Marks.

Experiments were carried out by Dr. Frost in the field over several years with various types of tag attached to the operculum and dorsal fin of the char. Some success was obtained with silver smolt-tags attached by wire to the dorsal fin and returns of up to 4 % were made, but there was evidence of the loss of tags. The opercular tags were unsatisfactory. Later, clipping various fins was tried. Removal of the adipose fin was unreliable, as although it did not regenerate completely, there was always an element of doubt involved in distinguishing a marked fish. Removal of part of the ventral lobe of the caudal fin was also unsatisfactory due to the frequency of fish with naturally damaged or worn tails. Clipping of the dorsal lobe of the caudal fin was better, but still unreliable because of regeneration.

Over the winter of 1949—50, char marked with several different tags and fin clips were kept in fish ponds and observations made, when the pond was drained, on the state of the marks and survival of the fish. The following marks were used:—

1. Dorsal lobe of caudal fin clipped.
2. Ventral lobe of caudal fin clipped.
3. Adipose fin removed.
4. Anal fin removed.
5. Left pelvic fin removed.
6. A metal tag attached with prongs through the hypural bones at the base of the tail (designed by Mr. G. J. Thompson).

7. Subcutaneous tags placed under the skin of the back, made of Monel metal, silver, stainless steel, and celluloid.
8. Similar tags placed in the body cavity.
9. Double tags of silver joined by silver wire, or of celluloid joined by plastic ("Saran") thread. One half was placed under the skin, the other lay outside the fish.
10. Similar tags with one half in the body cavity.
11. Silver wires attached through the base of the dorsal fin.

In addition there were unmarked control fish. Although it was impossible to obtain results after any period longer than two-and-a-half months, by then it was clear which of the marks showed most promise. The clipped anal and pelvic fins showed very little sign of regeneration compared with the others and also showed little indication of being deleterious to the health of the fish. The wounds made in inserting the body-cavity tags (8 and 10) and the double tags under the skin were still unhealed, but the fish with the single subcutaneous tags (7) were much healthier. The tail tag (6) showed signs of causing irritation and in some cases the skin was beginning to cover it up. Several of the wires under the dorsal fin (11) had come out during the experimental period. Therefore, as the single subcutaneous tags and the clipped anal and pelvic fins showed most promise of success, further experiments were concentrated on these.

Results from the Use of Subcutaneous Tags.

a) Survival trials in ponds.

Preliminary trials were carried out from 6. December 1949 until 22. February 1950, when a variety of marks was tested. The results for the controls, fin-clipped fish, and subcutaneous tags are summarized in Table 1. The "dorsal caudal" clipped fin was the removal of a small triangle of fin off the upper lobe of the tail. It will be seen that neither

Survival of marked and control fish in a pond.

Table 1. From 6. December 1949 until 22. February 1950.

Type of mark	Number of fish stocked	Number of fish recovered
Controls	15	15
Dorsal caudal	11	8
Anal	6	6
Left pelvic	8	6
Total with clipped fins	25	20
Monel subcutaneous tag	8	6
Silver „ „	7	7
Celluloid „ „	9	9
Stainless steel „ „	3	2
Total tagged	27	24

Table 2. From 15. December 1950 until 28. May 1951.

Type of mark	Number of fish stocked	Number of fish recovered
Controls	15	12
Subcutaneous tag and anal fin clip	15	9
Subcutaneous tag only	5	3
		+1 tag lost
Anal fin clip only	5	4
Total	40	29

Table 3. Summary of marking experiments in River Brathay.

Year of marking	1948		1949		1950		1951		Total catch
Type of mark	Clipped caudal fin		Silver wire		Subcutaneous tag and clipped anal fin		Subcutaneous tag and clipped pelvic fin		
Year of capture	Number	%	Number	%	Number	%	Number	%	
1948	**46**	**100**	—	—	—	—	—	—	77
1949	16	35	**89**	**100**	—	—	—	—	239
1950	7?	15?	5	6	**331**	**100**	—	—	365
1951	0	0	0	0	49	15	**69**	**100**	121
1952	0	0	0	0	41	12	20	29	124
1953	0	0	0	0	4	1	0	0	68

clipping the fins nor the subcutaneous tags caused any significant mortality.

In the second set of trials the char were stocked in March 1950 but no fish were recovered when the pond was drained in October 1950, probably because the summer temperatures were lethal. On 15. December a third experiment was started and the pond was drained and the fish examined on 28. May 1951. The results are shown in Table 2. It will be seen that there was a slightly higher mortality among the tagged than the untagged fish, but this difference is not significant, and the numbers involved are too small to give conclusive results.

On 26. September 1951 a fourth experiment was started, this time using 60 yearling brown trout (*Salmo trutta* L.) and keeping the fish for a year in hatchery stew-ponds. No mortality was recorded among any marked or control fish, but all the tags had been sloughed out by the end of the year.

b) Recoveries of tagged fish in field experiments.

Investigations over a number of years have been concentrated on four of the spawning grounds of the Windermere char — the autumn spawning in the river Brathay, at Low Wray Bay, and at Red Nab, and the spring spawning at Holbeck. A number of marking experiments has been carried out at these localities involving the marking of spawning fish and their recapture in subsequent spawning seasons, one, two, and three years afterwards. Except at Low Wray Bay, where a gill net was used, the fish were caught in seines drawn over the spawning ground on a number of occasions during the spawning season. A summary of the results of these experiments at Brathay, Red Nab, and Holbeck are given in Tables 3 and 4. These results give an indication of the rates of recapture of marked fish obtainable in field experiments and thus an indication of the success of the methods of marking. The first two experiments at Brathay involved a simple clipped fin and a wire tag and thus give data for comparison with the subcutaneous tag plus clipped-fin method. The percentage recovery of these marked fish will have depended not only upon the success of the method of marking but

Table 4. Summary of marking experiments at Red Nab and at Holbeck.

(a) Red Nab.

Year of marking	1950		1951		Total catch
Type of mark	Subcutaneous tag and clipped anal fin		Subcutaneous tag and clipped pelvic fin		
Year of capture	Number	%	Number	%	
1950	**146**	**100**	—	—	243
1951	18	12	**494**	**100**	549
1952	11	8	47	10	427
1953	3	2	17	3	236

(b) Holbeck.

Year of marking	1951		1952		
1951	**36**	**100**	—	—	41
1952	2	5	**920**	**100**	987
1953	0	0	236	26	673

also upon the natural survival rate, the proportion of fish that returned to the same spawning ground, and the intensity of the fishing effort in the years of recapture. The marking experiments indicate that most but not all the fish return to the same spawning ground year after year, but the spawning area is probably larger and more diffuse at Red Nab and Low Wray Bay than at Holbeck and Brathay. The intensity and success of the fishing operations also varied from year to year. It will be seen from Tables 3 and 4, however, that rates of recapture one year after marking of up to 29 % were obtained with the subcutaneous tag. Further, taking into account the variations in rate of fishing, returns of a similar order were obtained at Brathay from the subcutaneous tag as were obtained from the simple clipped caudal fin. The low returns of fish marked with wires are almost certainly due to loss of the wires. At Low Wray Bay 114 fish were marked in 1950, four recaptured in the same net in 1951 and two in 1952; there may in this case have been some mortalities among the fish as they were marked after being caught in a gill net. In addition to these returns from the spawning grounds, eighteen marked char were caught by anglers, one tag was recovered from the stomach of a pike, and a few were caught on a different spawning ground from that at which they had been marked.

Without sound information on the natural mortality and the proportion of fish that did not return to the same spawning ground, it is impossible to say whether the marking had any effect upon the survival of the fish, but there does not seem to be any evidence that the marked fish had a survival rate much less than that of unmarked fish.

The rates of recaptures were analysed in relation to the size of the fish marked, and the results showed that, within the normal adult range, size had no significant effect upon the chances of recapture. A total of 37 "dwarf" male char (from 15 to 21 cm. in length) were, however, marked in the same way and none was recaptured more than a few

days after marking. These negative returns, although not quite statistically significant, do suggest that these very small fish were adversely affected by the marking.

c) State of recovered marked fish.

When marked fish were recaptured they were examined for fin regeneration and the state of the wound where the tag had been inserted, and measured to record the increment in growth they had made.

Fish examined after 2—5 months in the experimental ponds showed hardly any regeneration of clipped fins except for the adipose fins,

Table 5. Analysis of fin regeneration.

Regeneration category	Anal fin				Pelvic fin			
	After 1 year		After 2 years		After 1 year		After 2 years	
	Number	%	Number	%	Number	%	Number	%
Nil	2	22	4	11	95	39	4	21
Slight	7	78	21	60	121	50	5	26
1/4	0	0	0	0	5	2	7	37
1/2	0	0	8	23	22	9	0	0
3/4	0	0	2	6	0	0	2	11
Totally	0	0	0	0	0	0	1	5
Totals	9	100	35	100	243	100	19	100

which often required careful examination to be sure that there was something abnormal about them. The anal fins had healed after two months and at five months some of them showed a slight "frill" as the beginning of regeneration. The fish recaptured in the field in the 1951—52 season had their fin regeneration recorded in the arbitrary units: nil, slight, 1/4, 1/2, 3/4, and totally. The results of these examinations are set out in Table 5. It will be seen that most of both the anal and the pelvic fins showed little or no regeneration even after two years, but that in a few fish the fins had regenerated to nearly their original size. In every case the fins could readily be recognized by experienced observers as having been clipped, and in the case of the pelvic fin the new growth was invariably twisted or deformed. A few of the clipped anal fins might, however, have been missed by fishermen giving only a cursory examination. Such fin regeneration as occurred could not be obviously correlated with any other characteristics, such as the size of the fish when marked.

The wounds in the skin of the char where the tags had been inserted were found, on recovery of marked fish, to be in a variety of conditions. In many fish the small slit had healed completely, leaving a small scar visible only on careful examination. In some of these fish, however, the skin was raised in a marked blister and the muscles beneath were also eroded to form a distinct hollow, turgid with a yellow liquid, in which lay the tag. In one or two extreme cases the blister was about 25 mm. long, 15 mm. wide, and perhaps 10 mm. deep. In other instances there was only a slight suspicion of swelling and only a small quantity

of fluid surrounding the tag. In many other fish the slit where the tag had been inserted had not completely healed, leaving a small hole in the skin about 1 to 2 mm. in diameter. In a very few fish there was a second hole in the skin opposite the other end of the tag. In no case where there was still any unhealed hole was there any sign of a blister or fluid. In a number of other fish (recognized as marked by their clipped fin or scar of the tag wound) the tag had been lost; in

Table 6. Analysis of state of tag wounds of recovered marked fish.

Time till recapture	1 year		2 years		Total	1 year
Spawning group	Brathay	Red Nab	Brathay	Red Nab	Autumn	Holbeck
			Numbers			
Completely healed	17	26	9	3	57	9
Slight blister	7	13	2	0	24	7
Large blister	9	12	1	1	24	11
One unhealed hole	17	11	6	3	40	131
Two unhealed holes	4	1	0	0	5	2
Tag lost	7	4	11	12	36	52
No record	12	5	12	9	43	23
Totals	73	72	41	28	229	235
			Percentages			
Completely healed	23	36	22	11	25	4
Slight blister	10	18	5	0	10	3
Large blister	13	17	2	3	10	5
One unhealed hole	23	15	15	11	18	56
Two unhealed holes	5	1	0	0	2	1
Tag lost	10	6	27	43	16	22
No record	16	7	29	32	19	9
Totals	100	100	100	100	100	100

nearly every such case it had evidently come out through the slit of insertion.

For most of the marked fish recovered, records were made of the state of their tag wounds, and these were classified into six categories. The results of the analysis of these records are given in Table 6. It will be seen from this table that the different groups of fish marked show significantly different proportions among the different types of tag wounds. The reason for this is not obviously apparent, but it may be due to the different location of the tag on the fish among the different groups of marked fish (the tag was inserted on the left-hand side for autumn spawners, anterior to the dorsal fin at Brathay, beneath the dorsal fin at Low Wray Bay, and posterior to the dorsal fin at Red Nab. At Holbeck the tag was placed on the right-hand side anterior to the dorsal fin). There did not seem to be any definite association in the proportions of the main types of tag wounds with fish recaptured one, two, or three years after marking, whether or not they had been recaptured and had their tag examined on an intervening

occasion; nor was there any correlation between tag wound and the size of the fish. It does not seem as if any conclusions can be drawn from these differences in the way the tag wounds healed, nor is it apparent that lack of a healthy, healed tag wound has been of any disadvantage to the marked fish.

The rate of loss of tags is, however, of some importance. It will be seen from Table 6 that the proportion of marked fish that had lost their tags varied among the groups of fish and tended to increase with time. Over all, about 20 % of the fish lost their tags. There was no correlation between the rate of tag loss and the size of the fish when marked. In the small experiment with tagged and untagged trout (*Salmo trutta* L.) kept in a hatchery stew-pond all the tagged fish had lost their tags in approximately one year from marking. This indicates that with other species and under other conditions retention of the subcutaneous tag may be poor. It is not possible to estimate directly the rate of tag loss among fish that had their tag examined and were then released again, but the rates of recapture a second and third time of such fish indicate that removal, examination, and replacement of the tag had no effect on its retention. Thus it may be concluded that tag losses may vary, will increase with time, but will average about 17 % for one year.

All the fish were measured on marking and recapture so that the increment in length made is known. The lengths were recorded to the nearest 1 mm. and although the measurement of live char cannot be very accurate and an error of up to several millimetres is possible (K i p l i n g, unpublished data) on average, as there is no bias, such errors should cancel out. The individual increments recorded for marked fish (mostly over a period of one year) ranged from +48 mm. to —9 mm., averaged 6·3 mm., and varied greatly among individuals, with the size of the fish, and with the spawning group. There was also variation with the state of the tag wound but this was neither consistent nor statistically significant. At Holbeck the mean increment of the smaller fish (<28 cm.) was 28·5 mm. and the increments decreased with the size of the fish till the largest fish (>34 cm.) had an average increment of —0·5 mm. For the autumn spawners the mean increments decreased from 17·7 mm. for fish less than 27 cm. to 1·2 mm. for fish larger than 31 cm.

According to F r o s t (1951 and personal communication) the adult spring-spawning char are normally larger and faster growing than the autumn spawners. From scale readings she finds that char similar in size to the smaller ones marked (i.e., <28 cm.) have an annual growth-increment of about 25 mm. This is not significantly different from the increments made by the smaller marked fish. The readings of scales from larger fish, however, give a rather larger increment than the results from the marked fish, and also do not show the same decline in growth with increase in size that is shown by the marked fish. These differences may be due to the effect of marking on the growth of these larger fish. On the other hand, it seems unlikely that the inhibitory

effect of marking on growth should become apparent only at about 28 cm. length and increase with increase in size of the fish above 28 cm. It is quite possible, however, that part at least of the differences in growth increment shown are due to the difficulties or impossibilities of making valid interpretations of the edges of the scales of these old and slow-growing fish. Thus although it may be concluded that the marking had little effect upon the growth of the smaller fish, it is not yet possible to draw conclusions about its effect upon growth in the larger fish.

d) The effect of the removal and replacement of the tags.

Nearly all the marked fish recaptured were released again alive after the number on their tag had been read. A small new slit was cut (or the old unhealed slit enlarged), the tag removed with fine forceps, the number read, the tag then replaced, and the fish released again. This operation could usually be performed as easily as the marking of an unmarked fish. In later years several of these fish were recaptured for a second time and two char marked in 1950 were recaptured in 1951, 1952, and 1953. Both at Red Nab and at Brathay the rates of recovery made in 1952 were very similar for fish marked in 1950 and recaptured and released again in 1951, and for fish marked for the first time in 1951, so that it does not seem as if the examination of the tag had any influence on survival and the chances of subsequent recapture. Nor, as noted in the sections above, was there evidence that examination of the tag had any influence on either the state of the tag wound, the loss of tags, or growth.

Discussion and Conclusions.

It will be appropriate to review and summarize the results obtained with the subcutaneous tag with reference to the requirements of an ideal fish mark that were set out in the Introduction.

Provided the tag is not lost, individuals can be distinguished at least at intervals of a year, as it does seem as if removal, examination, and replacement of the tag has no deleterious effect (in most marking experiments the recaptured fish is killed for examination and not released again, so the need to replace a subcutaneous tag would not arise). A tag that is visible externally would be an improvement, but this would only be possible with a subcutaneous tag used on a fish having a much less pigmented skin than the char. The ease and speed of the marking operations have proved satisfactory for numbers of fish of the order used in the experiments described. The simple tags are also inexpensive to make.

The conclusions that can be drawn about the effect of the tagging on the survival, growth, and general health of the fish are to some extent still tentative, but sufficient evidence has been collected over a long enough period to show that the tagging cannot have any great effect upon the fish. The rates of recapture were more than adequate

to provide most of the information sought by the marking experiments, and the method was more satisfactory in this respect than any other previously tried.

The rate of loss of tags was higher than desirable, but the clipped fin insured that loss of the tag did not mean the loss of all the information obtainable from a marked fish. There is scope for further investigation into the problem of lost tags. It is quite possible that a differently shaped tag or one made from another material might prove more satisfactory. As it was found easy to detect the tags, there would be no need to use a magnetic or metallic material capable of electronic detection. Some slightly different tag is evidently needed for the small char and trout that seem to be difficult to mark successfully with the present tag.

Although it is possible that a few marked fish were not recognized as such by anglers, in general the clipping of the fins proved satisfactory and regeneration was not enough to interfere with recognition. Taking into account the probable special function of the anal fin in the spawning of salmonids (Jones & King, 1949), we consider that one of the pelvic fins is probably the best fin to clip.

It may be concluded that although in its present form some tag losses can occur and there may be some slightly deleterious effect upon the fish, the subcutaneous tag plus a clipped pelvic fin can give successful results with the adult char and compares favourably with other methods of marking. It probably also has considerable scope for further development and trials with other species.

Summary.

After preliminary trials of several different marks on the char a subcutaneous Monel metal tag was tried in conjunction with a clipped anal or pelvic fin. As a result of several field experiments, returns of up to 29 % were obtained after one year and smaller percentages after two and three years' absence. Though the data are not quite conclusive the marking appeared to have had only slight effect upon the survival, growth, and health of the fish. Nearly 20 % of the fish lost their tags. Further improvements seem possible, and the method may prove useful where external tags are unsuccessful.

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A Portable Instrument for the Location of Subcutaneous Fish-Tags.

By

W. H. Moore and **C. H. Mortimer,**

Freshwater Biological Association,
Ambleside, Westmorland.

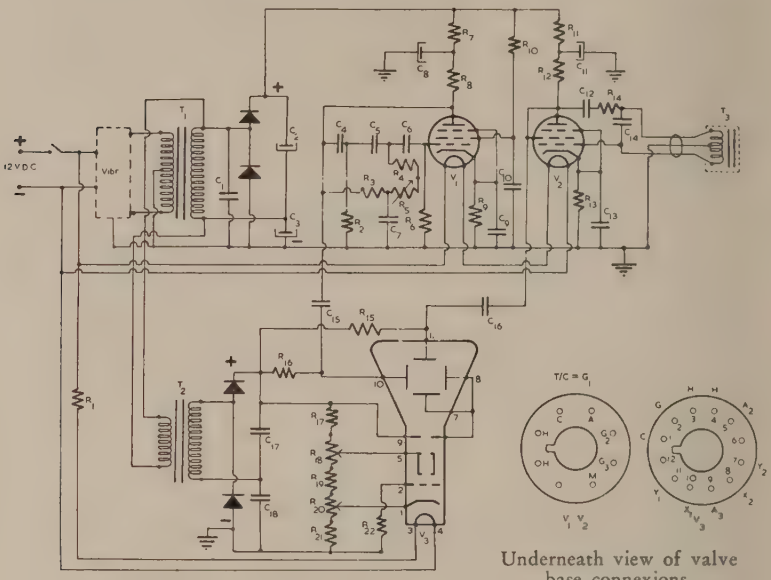
Principle of operation.

Methods of detection of metal fish-tags (D a h l g r e n, 1936) or of metal impurities in foodstuffs (Cinema-Television Ltd., 1952) are well known. Our problem was to construct a simple, portable instrument, using available (mainly war surplus) components. The instrument had to be sufficiently robust and weatherproof for use during netting operations in the field, and capable of detecting small metal tags of the type described in the fore-going paper (L e C r e n, 1954), even when embedded several millimetres below the skin of a fish. It was found possible to do this with tags of Monel metal (an alloy containing 60 % nickel, 33 % copper, and 6·5 % iron) of the dimensions 15 × 4 × 0·25 mm., the ferromagnetic properties of which rendered detection easier than when other metals, such as silver, were used. The Monel metal tags also appeared to cause the fish no harm (L e C r e n, 1954).

The instrument is of conventional design (Figure 1), and the brief description given here should be adequate to enable those with some knowledge of electronics to construct a similar device. A search coil on a flexible cable forms part of an oscillator circuit, the frequency of which changes slightly when a tag is approached. This change is detected by the beat method, using a second oscillator of pre-set frequency and a cathode-ray oscilloscope (C. R. O.) as a beat detector.

Construction

The search unit is an inductance taken from a radio-sonde (T h o m a s, 1938; Meteorological Office, 1943). It consists of two coils of 1250 turns of 38 s.w.g. copper wire, one on each limb of a U-shaped laminated core of mumetal. This is fitted into a sealed box of Tufnol, made by drilling out a block as shown in Figure 2, so that the poles, P, of the laminated mumetal core are flush with the side to



Underneath view of valve base connexions.

Figure 1. Circuit diagram of the portable fish-tag detector.

C_1 — ·25 MFD
C_2, C_3 — 8 MFD
C_4, C_5, C_6 — ·005 MFD
C_7, C_{12} — ·01 MFD
C_8, C_{11} — 4 MFD, electrolytic
C_9, C_{10}, C_{13} — ·1 MFD
C_{14} — ·05 MFD
C_{15}, C_{16} — ·5 MFD
C_{17}, C_{18} — 2 MFD
T_1 — 9-0-9 V to 110 V
T_2 — 3 : 1 Intervalve Audio-Transformer
T_3 — Search Unit (Inductance from Radio-Sonde, cf. Fig. 2)
Vibr: 12 V D.C. Input Vibrator 18 V A.C. output centre tapped
V_1, V_2 — VR65 (CV1065. ARP36)
V_3 — VCR139A (CV1588)

R_1 — 7·3 Ω
R_2 — 5600 Ω
R_3 — 39000 Ω
R_4 — 29200 Ω
R_5 — 2500 Ω Potentiometer
R_6 — 560000 Ω
R_7 — 15000 Ω
R_8, R_{12}, R_{14} — 20000 Ω
R_9 — 390 Ω
R_{10} — 100000 Ω
R_{11} — 22000 Ω
R_{13} — 220 Ω
R_{15}, R_{16}, R_{22} — 1 M Ω
R_{17} — 220000 Ω
R_{18} — 25000 Ω Potentiometer
R_{19} — 27000 Ω
R_{20} — 2000 Ω Potentiometer
R_{21} — 1000 Ω

be held against the fish. This unit is connected to its appropriate oscillator, which we may call the search oscillator (V_2, Figure 1), inside the instrument case by a 6 ft. length of flexible rubber-covered 3-core cable. The frequency of the search oscillator is approximately 900 cyc./sec. The second oscillator (V_1, Figure 1), which we may call the pre-set oscillator, takes the form of a modified parallel-T circuit (E s p y, 1948) with a part, R_5, of the resistance network made variable so that the

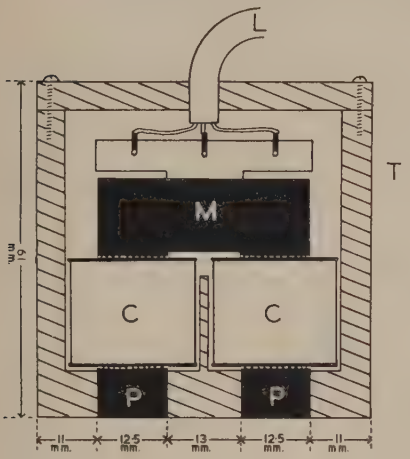


Figure 2. Section through the search unit. T = Tufnol block drilled out to accommodate a radio-sonde inductance, which consists of coils C, laminated mumetal core M, with poles P. L = 6 ft. (2 m.) flexible lead.

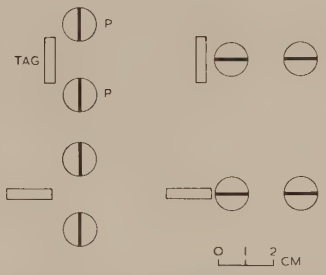


Figure 3. Range at which the presence of a Monel metal tag, 15× 4×0·25 mm., can just be detected. The diagram, which is to scale, gives the range at different relative orientations of tag T and poles P of the search unit, when the tag and pole surfaces are in the same plane.

frequency can be set at any value between 895 and 915 cyc./sec. Apart from the battery switch, R_5 is the only external control: it is used to balance the frequencies of the two oscillators. The output from the search oscillator is applied, without amplification, to the Y_1 plate, and that from the adjustable oscillator to the X_1 plate of the C. R. O., and frequency balance is indicated by a stationary elliptical trace on the screen as described in the following section.

Details of design (cf. Figure 1) were dictated by the components available; other oscillator and oscilloscope circuits could serve equally well. Power is provided by a 12 V accumulator at a total drain of 2·4 A. Thus an accumulator of about 20 ampere-hours capacity should be ample for a normal day's operations. All filaments are supplied from the battery directly. The filaments of the oscillator valves (V_1 and V_2; 6·3 V, 0·3 A) are connected in series, while that of the cathode-ray tube (V_3; 4 V, 1·1 A) is supplied through the dropping resistance R_1. H.T. supplies (210 V, 6 mA total for V_1 and V_2; 560 V, 3 μA beam current for V_3) are provided by a 12 V A.C. non-synchronous vibrator followed by a step-up transformer (an intervalve audio-transformer is used for T_2) and metal rectifiers in voltage doubler circuits. It was found that the cathode to filament insulation of the cathode-ray tube was low, so that the 560 V H.T. supply had to be connected with its negative side to earth, and not its positive as is usual in C. R. O. circuits. Brightness and focus controls for the C. R. O. were placed inside the instrument case and pre-set.

The instrument weighs 16 lb. (7·25 kg.) without the battery.

Adjustment and operation.

After switching on, the instrument is allowed to warm up for about ten minutes, and R_7 is then adjusted until zero beat between the oscillators is obtained, with the search unit held away from metals. Even after warming up it may be found that the ellipse may sometimes be distorted and subject to intermittent slow rotation. This is due to changes in the voltage supplied by the vibrator; the effect disappears if better regulated H.T. supplies are used. However, this slow rotation does not interfere with tag detection. When the search unit is passed along the skin of a fish and approaches within 10 mm. of a tag, the trace begins to revolve more rapidly, until just over the tag, i.e., less than 5 mm. from it, the trace rotates at more than 5 cyc. sec. and is deformed into a complex Lissajou pattern with a square envelope. The range at which a tag can be detected depends somewhat on its orientation relative to the pole pieces of the search unit. The results of laboratory tests relating to "horizontal range", i.e., with pole pieces and tag both on a piece of paper, are summarized in Figure 3. "Vertical range", i.e., with the pole pieces directly above the tag, again depends on the relative orientation. With tag and pole pieces separated by a 7 mm. spacer of Perspex, and with the tag centre vertically below the mid-point of the line joining the pole centres, the trace revolved rapidly when the tag lay along the line, but only slowly if it lay across it. With a 3 mm. spacer the respective rates of rotation were just above and just below 5 cyc./sec.

As already mentioned, the initial adjustments for "brilliance" and "focus" of the trace were made by means of the pre-set variable resistances R_{10} and R_{14}. The dimensions and shape of the trace on the screen were also initially set by choosing suitable values for R_7 and R_{13}, i.e., by setting the anode current passing through V_1 and V_2. With the values given in Figure 1 the trace was roughly circular with a diameter of about 20 mm. Incidentally it was also discovered that V_2 ceased to oscillate if the search unit was placed on a large mass of iron.

Summary.

An instrument is described which will detect subcutaneous fish-tags of Monel metal (15 × 4 × 0·25 mm.) at a range of 10 to 20 mm. depending on orientation.

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The Efficiency of the Cornish Pot and the Scottish Creel in the Capture of Lobsters and Crabs.

By

H. J. Thomas,

Marine Laboratory, Aberdeen.

Introduction.

Differences existing in the relative efficiencies of various modifications of the Scottish-type creel have been demonstrated by Thomas (1953) who has discussed their possible significance in the estimation of population statistics. The differences investigated were small when compared with the wide variation in gear employed in the capture of lobsters and crabs in other parts of Britain, as well as in other countries. It may be that a trap which is well suited to a particular coast will prove less well adapted for use in some other area where tide, depth of grounds, bottom, quantities of seaweed, etc. may require a considerable variation in design. Furthermore, from the fishermen's standpoint, workability — a factor which is very difficult to assess — is of considerable importance.

Two main types of trap are used in the capture of lobsters and crabs in Britain. The Cornish-type pot is the principal device employed off the south and west coasts of England. Around the remainder of the coast of Britain a braided network trap is employed, basically similar to the Scottish creel as used by Thomas (1953).

The present investigations into the relative efficiencies of the Cornish pot and the Scottish creel were carried out by the Fishery Research Vessel "Kathleen", of the Scottish Home Department, working in Orkney waters during September in 1951 and 1952.

Thanks are due to Mr. J. A. Pope of the Marine Laboratory, Aberdeen, for his assistance in the statistical treatment of the results

Material and Methods.

Cornish pots are roughly hemispherical in shape (Figure 1). They are built of wicker-work, usually from hazel or willow. The flat base is circular, of close basket-work, of diameter 2 ft. 3 in. The sides are formed from wands which are brought upwards and then inwards, and finally bound downwards centrally to form an eye at the top of the pot; the height of the pot is 1 ft. 8 in. and the depth of the eye 7 in., its diameter 8 in. Wands forming the sides of the pot are at a separation of $1\frac{1}{2}$ in. and bound together by a spiral of willow twigs, which generally circle the creel twice in passing from the base to the eye. The eye itself is closely bound by twigs to form a funnel leading into the top of the pot.

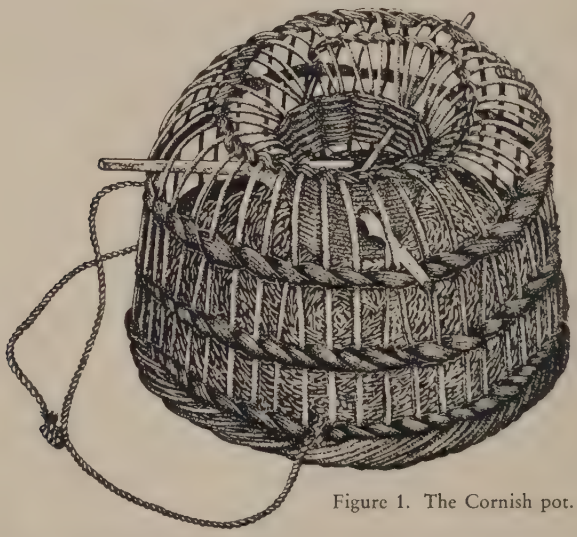

Figure 1. The Cornish pot.

Bait is secured in the creel by means of skewers, made of wood and 15 in. in length. The bait is fixed to the skewer which is then passed through the mouth of the creel and the point of the skewer is inserted in the close basket-work of the funnel, so that the point of the skewer projects downwards and inwards to the centre of the funnel. Generally three such baited skewers are used. The points of the three skewers converge to the centre point of the funnel; sometimes four or even five skewers may be used. Fishermen hold that, providing the closed fist can be thrust into the space between the skewers, ample room is left for the lobster to enter the pot. The skewers not only secure the bait but prevent escape from the pot, particularly during hauling.

Pots of this type were obtained from a Cornish fisherman.

The design of the Scottish creel is described in "Practical hints for lobster fishermen" (Scottish Home Department, 1952). The variant

employed in these experiments was the double open-eyed type with the eye inlet lined with fine-mesh netting, as used by Thomas (1953). These were obtained from a Berwickshire fisherman.

Twenty-four Cornish pots and a similar number of Scottish creels were used in each fishing, the forty-eight traps being shot in six fleets each of eight traps. The arrangement of the pots and creels in each fleet was randomized. Fleets were shot in about 6—8 metres and were distributed along the coastline with an interval of about a quarter of a mile between fleets. The period of fishing was, in general, about twenty-four hours. A variety of baits was employed but in any one fishing the traps were baited similarly.

During 1951 both Scottish-type creels and Cornish pots were baited equally, using a whole salted mackerel or an approximately equivalent amount of other bait. It is customary for fishermen, who normally use the Cornish pot, to bait each skewer so that, in general, about three times the quantity of bait is employed as would be employed by the fishermen using the Scottish-type creel. The possible effect of this variation in the amount of bait was investigated during 1952 when each trap, both Cornish and Scottish, in three of the six fleets were baited with one-and-a-half salted mackerel whilst the traps of the remaining three fleets were baited with half a salted mackerel.

All lobsters caught were measured from the tip of the rostrum to the end of the telson, excluding the setae, with the abdomen fully extended. Crabs were measured at the maximum width of the carapace. The statistical treatment of results followed the procedure employed by Thomas (1953).

Results.

Fishings were made during 1951 with the Cornish pots and Scottish creels equally baited. The total catch of lobsters, by fleets, at each fishing by all traps of each type is shown in Table 1.

Table 1.

Total number of marketable sized lobsters caught by Scottish creels and Cornish pots, respectively, by fishings.

Fishings	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Scottish creel	4	2	4	1	6	4	1	3	3	7	4	8	9	3	3	4	66
Cornish pot	6	1	2	4	8	4	1	1	1	4	3	3	4	3	1	2	48

An analysis of variance was carried out, the results of which indicate that there is no significant difference in the numbers of lobsters caught by the two kinds of trap.

Table 2 gives the number of crabs caught by the Scottish creels and Cornish pots, respectively, in each of seventeen fishings.

As in the case of lobsters, there is no significant difference in the numbers of crabs caught by the two types of trap.

Statistical analysis of the length of lobsters taken by the Scottish

Table 2.

Total number of marketable sized crabs caught by Scottish creels and Cornish pots, respectively, by fishings.

Fishings	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
Scottish creel	10	11	1	0	0	10	4	13	6	3	2	4	2	7	4	6	8	91
Cornish pot	16	11	6	2	3	7	1	10	1	0	9	2	1	4	2	2	9	86

creel and Cornish pot also reveals no significant difference between the two traps. On the other hand, analysis of the difference in the carapace width of marketable sized crabs shows that the Cornish pot took a significantly larger mean size than did the Scottish creel, the average mean widths being 13·85 cm. and 13·14 cm., respectively. The statistical test shows the difference of 0·71 cm. ± 0·31 cm. to be significant at the 5 % level.

During September 1952 a test was carried out in which each trap of three fleets was baited with one-and-a-half salted mackerel (triple baiting) as normally employed in the use of Cornish pots, and the other three fleets were baited with half a salted mackerel (single baiting). The results of this experiment are shown in Table 3.

Table 3.

Total number of lobsters caught by Scottish creels and Cornish pots with single and triple baiting, respectively, by fishings.

Fishings	1		2		3		4		5		6		7		8		Total Single Baitings	Total Triple Baitings	Overall Total
Baiting*)	S	T	S	T	S	T	S	T	S	T	S	T	S	T	S	T			
Scottish creel	7	3	6	7	0	2	2	7	5	5	2	6	2	1	3	1	27	32	59
Cornish pot	6	2	4	7	0	4	10	7	2	3	6	2	1	0	0	2	29	27	56
Total	13	5	10	14	0	6	12	14	7	8	8	8	3	1	3	3	56	59	115

*) Single = S. Triple = T.

An analysis of variance was carried out, the results of which indicate that the differences between Scottish creels and Cornish pots with both single and triple baitings are not significant, nor is the overall difference between single and double baitings, taking both types of creel together, significant.

Discussion.

The experiments show that under specified fishing conditions in Orkney waters during September, the difference between the catching power of the Scottish creel and the Cornish pot was negligible. On the other hand, a generalization to this effect could not be made without a corresponding test being carried out in Cornish waters, whilst fishing at other seasons and under different conditions is also desirable.

The efficiency of a trap in the capture of lobsters and crabs is only

one of several factors in the efficiency of the fishery. It is suggested in "Practical hints for lobster fishermen" (Scottish Home Department. 1952) that, in general, boats of 30—35 ft. keel length, manned by two or three fishermen, each fishing 100—150 traps shot in fleets of 20—50 creels, constitutes probably the most efficient fishing method. This presupposes suitable grounds and conditions. The smaller the trap the more can be carried in a given size of boat, and, provided entry of lobsters is not impaired, a corresponding increase in efficiency should be possible.

The ability of the trap to withstand weather is an important factor. Barrel-shaped traps supposedly have an advantage in this respect. It is claimed that the two-compartment trap, such as the Nova Scotia creel, has an advantage in diminishing the number of escapes. Local conditions, and even the season, may also be a factor in determining the relative efficiency of the various designs.

A comprehensive test of the factors governing the overall efficiency of the fishery using various types of trap is desirable. However, notwithstanding the results of any such experiment, the local availability of materials, as well as tradition, will inevitably continue to be a determining factor in the methods which are adopted.

Summary.

(1) Under specified fishing conditions no significant difference exists in the efficiency of the Scottish creel and the Cornish pot in the capture, by number, of either lobsters or of crabs. This result applies even though Cornish pots are baited with three times the quantity of bait used in the Scottish creels.

(2) No significant difference exists in the size of lobsters caught by the two types of trap. The Cornish pot catches crabs of a slightly larger size than does the Scottish creel.

(3) Some of the factors governing the overall efficiency of lobster and crab fishing when using certain varieties of traps are discussed.

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Reviews.

J. Proudman. "Dynamical Oceanography". pp. 409. Methuen & Co., London, 1953.

Die physikalische Ozeanographie ist in den letzten fünfzig Jahren zu einem sich immer mehr entwickelnden Teilgebiet der Geophysik geworden und so ist es nicht verwunderlich, dass bei diesem Übergang von einer rein deskriptiven Wissenschaft zu einer geophysikalischen Vertiefung derselben mehr die inneren physikalischen Zusammenhänge der ozeanischen Erscheinungen naturgemäss in den Vordergrund treten und die theoretische Physik zu einem der wichtigsten Hilfsmittel der Forschung geworden ist. Das Proudman'sche Buch über dynamische Ozeanographie zeigt in eindringlicher Form, wie weit die exakte ozeanische Forschung zur Aufhellung der Dynamik des Meeres gekommen ist. Man muss von Seite der physikalischen Ozeanographie sehr erfreut sein, eine solche Darstellung des gegenwärtigen Standes der theoretischen Forschungsrichtung zu besitzen, umsomehr als das meiste, was im Buche geboten wird, sonst nur in Abhandlungen, oft nur in nicht leicht zugänglichen Zeitschriften zu finden ist. Die Darstellung der Probleme ist klar und deutlich und erlaubt auch den Nichtspezialisten, sich in die Materie hineinzuarbeiten. Sie ist, auf was ich besonders hinweisen möchte, kurz und präzis, wie dies auch sonst die vielen Abhandlungen Proudmans auszeichnet, so dass man bei den Darlegungen fast von einem "Proudmanschen Stil" reden könnte.

Der Natur der Sache entsprechend hat Proudman sich einer weitgehenden Spezialisierung der Probleme der Dynamik des Meeres bedient wobei die Vorgänge in den tatsächlichen Ozeanen nur selten etwas eingehender behandelt wurden. Diese Konzentration auf typische Fälle in Form einer Modellbehandlung lässt aber den Einfluss der wirksamen Faktoren klarer herausarbeiten und ist didaktisch sehr zweckmässig. An einzelnen Stellen des Buches wurden die abgeleiteten theoretischen Beziehungen zwar in ausgewählten Beispielen mit den entsprechenden Beobachtungstatsachen verglichen, aber diese Betrachtungen blieben in der Hauptsache qualitativer Natur. Der Referent hätte gewünscht, dass diese Zusammenhänge mit den Ergebnissen der Beobachtungen etwas eingehender und breiter ausgefallen wären. Aber der Autor hat doch am Schluss eines jeden Kapitels die wichtigste Literatur und kurze geschichtliche Hinweise über die besprochenen Probleme gegeben und so jedem die Möglichkeit gegeben, sich in die Probleme an der Hand der Originalabhandlungen zu vertiefen. Die benützten mathematischen Hilfsmittel

beschränken sich auf einfache Operationen, die elementare Differentiationen und Integrationen nicht überschreiten. So ist das Buch zu einem Einführungsbuch der physikalischen Ozeanographie geworden, das besonders, wie der Autor hervorhebt, "zum Studium für Studenten und solchen, die praktische Ozeanographie treiben", von grossem Nutzen sein wird.

Kapitel I—V behandeln nach Darlegung der Grundbegriffe die einfachen Grundlagen der Dynamik der Meeresströme, hier noch ohne Berücksichtigung der Reibung und Turbulenz, während in den Kapiteln VI—IX diese komplizierenden Faktoren, vor allem auch die Vermischung der Wassermassen im Meer in Rechnung gestellt werden. Auch der Frage der Erregung der Meeresströme durch Wind wird hier Aufmerksamkeit geschenkt. Das Kapitel X gibt in besonders interessanter und origineller Weise das im üblichen sonst sehr stiefmütterlich behandelte Problem der thermodynamischen Zirkulationen und die Frage der Bedeutung derselben für die ozeanischen Meeresströme. Die Kapitel XI—XVI bringen dann die Gezeiten, die Flut- und Oberflächenwellen und die internen Wellen längerer und kürzerer Periode mit kurzen Hinweisen auf ihr Vorkommen im Meer. Stets ist die Darstellung, die sich meistens auf idealisierte Beckenformen beschränkt, originell und prägnant in der Herausarbeitung des Wichtigen und Grundlegenden.

Das P r o u d m a n' sche Buch ist das erste, das in englischer Sprache eine Übersicht über den Stand der Forschung auf dem Gebiet der theoretisch-physikalischen Ozeanographie gibt. Es beschränkt sich ausschliesslich auf die Dynamik der Vorgänge im Meer, während andere Teile der physikalischen Ozeanographie nur gestreift werden. Ich bin der Überzeugung, dass dieses Buch einer exakten Darstellung vieler Erscheinungen im Meer im Wissensgebiet der Ozeanographie viel Nutzen stiften wird, dass es aber auch für die Meereskunde neue Freunde erwerben wird, besonders in den weiten Kreisen der Physiker und Geophysiker, die vielleicht bisher diesem Wissensgebiet etwas skeptisch gegenübergestanden sind.

A. Defant.

Klaus Wyrtki. "Die Dynamik der Wasserbewegungen im Fehmarnbelt I". Kieler Meeresforsch., **9**, 2, pp. 155—70, 13 Abb. Kiel, 1953.

The principal aim of the investigation was to study the water exchange between the North Sea and the Baltic, a question that has a very important bearing on the considerable increase in salinity observed during recent years in the inner parts of the Baltic. The author has paid particular attention to determining the relative effects of the different factors — wind and atmospheric pressure, water-level, internal stratification, surface and bottom currents — on the dynamics of the water exchange through the Belts. In addition, examples are presented to show the agreement between the values observed actually and those derived theoretically.

The study is based on observations of surface current and salinity made on board the "Halsskov Rev", "Fehmarnbelt" and "Gedser Rev" lightvessels, and on water-level records from Korsør and Gedser. In addition, a current-meter anchored west of the "Gedser Rev" lightvessel during the experiment provided data on current conditions in the deeper layers.

The local wind is a very important factor in producing surface currents in the vicinity of the "Fehmarnbelt", but gradient currents may also play a large part. Convection currents, on the contrary, are generally of minor effect; their influence is clearly distinguishable only when the other forces acting cease abruptly. The author provides a number of examples which show

the details of the process of water exchange. The general picture is as follows:— When in summer, the air-pressure over Scandinavia is high and the water-level in the Baltic is very high, the situation favours outgoing surface currents. These are usually not very strong, but frequently last 3 or 4 weeks. The outgoing surface current results in a displacement of low-salinity Baltic water through the Belts towards the southern part of the Kattegat, while an ingoing deep current resulting from the changed stratification carries high-salinity water into the Baltic. The discontinuity layer is, as a rule, very sharp and reaches over the Darsser Schwelle (the threshold at Darsser Ort) into the Baltic. This situation lasts as long as there is a rise of water-level towards the south in the Belts. Surface inflows occurring for relatively short periods are, as a rule, not able to alter the stratification; their only effect is to displace the salinity "front". Such an inflow may be caused, for instance, by the piling up of water in the Skagerak under the influence of cyclonic disturbances which move eastwards over the Scandinavian peninsula and produce a marked gradient in the Transition Area. Ingoing surface currents may also arise when the water-level in the western part of the Baltic has been lowered by westerly winds. The author shows by means of numerical examples that it is not during the periods of inflow in summer that the greatest amount of high-salinity water penetrates into the deeper layers of the Baltic, but that this occurs when the current changes from in- to out-going. In the situation characterized by surface inflow a strong internal stratification is produced, and as soon as the potential energy of this internal field changes into kinetic energy an inflow takes place in the deeper layers, which carries water of high salinity into the Baltic.

E. Lisitzin.

M. Gillbricht. "Untersuchungen zur Produktionsbiologie des Planktons in der Kieler Bucht." Kieler Meeresforsch. (Teil I), **8**, 2, pp. 173—195, 24 Abb. und (Teil II), **9**, 1, pp. 51—61, 14 Abb. Kiel, 1952.

Between June 1949 and June 1950 a number of vertical sections was carried out in the Kieler Bucht. Observations at 2½ m. intervals of depth were made; these included measurements of temperature, salinity, phosphorus, nitrite, oxygen, chlorophyll, plankton, and seston. The records have been used in three ways:— (a) to compare chlorophyll measurements with phytoplankton volumes and seston weights; (b) to make estimates of production; (c) to make estimates of phosphorus regeneration.

The chlorophyll comparisons are expressed in the form of four regressions, chlorophyll on phytoplankton volume in October and March and chlorophyll on seston in the same two months. The slopes of the former regressions differ between the two months and this is shown to be due to the different proportions of diatoms to dinoflagellates in spring and autumn. Diatoms are predominant in spring and dinoflagellates in autumn. The difference is that a diatom appears to contain twice as much chlorophyll as a dinoflagellate.

The slope of any of these regressions of μg. chlorophyll on plant volume does not pass through the origin, but cuts the positive ordinate. This is taken to mean that there is a proportion of chlorophyll in the sea that is not contained in the plants. However, the slopes of the regressions of mg. seston on μg. chlorophyll also cut the positive ordinate, which is taken to mean that there is a proportion of steston that does not contain chlorophyll. Thus it is concluded that there are two forms of detritus in the seston, one containing chlorophyll and the other not. Yearly variations of the two

components have been estimated. The peak abundance of the green detritus occurs in May and August, whereas the peak abundance of the colourless detritus occurs in mid-winter. Between 20 and 60 observations were used in each regression; no estimate of error is given. It does appear, however, from a cursory examination that the standard error of the slope of the two seston regressions might be quite high. It would be very interesting to establish what proportion of the green detritus is made up of living μ-flagellates and what proportion is made up of broken diatoms and dinoflagellates; it appears from Figure 21 that the quantity of green detritus is 400 % greater than the quantity of diatoms and dinoflagellates. If a large part of a chlorophyll estimate is derived from grazed plant material, it is useless as a measure of standing crop.

The second part of this paper is concerned with an estimate of production. The essence of this method lies in the examination of the vertical distribution of phytoplankton. Figure 3 shows the sinking of a population of *Chaetoceras curvisetus* for six days through $7^1/_2$ m. It is assumed that a proportion of diatoms sink 5 m. per day and that their loss from the depth of 5 m. from the surface is made good by production. From any vertical distribution, ratios of numbers at 5 m. to those at any lower depth may be derived; due to sinking, this ratio appears to increase exponentially with depth, and so the loss at each depth may be estimated. This loss is equated to the production at each depth and from this, plausible estimates of production are obtained. There is some evidence in the literature that dead diatom cells may indeed sink at this rate; the evidence that living diatoms sink at all is a little uncertain. It is now well known that oil or protein production in diatoms is controlled by variations in the phosphorus/nitrogen ratio and the sinking of living diatoms may well be affected by this. Field observations of sinking diatom masses have not been made since this fact was established and it appears from laboratory experiments that diatoms only sink in culture when nutrients begin to run low. If grazing by copepods were of only limited extent (the author assumes that zooplankton feed only on detritus), if diatoms sank at the assumed rate and the sea were still, this method of estimating production might be valid.

D. H. C.

G. S. Saetersdal. "The Haddock in Norwegian Waters. 1. Vertebral counts and brood strength variations of young fish." Fiskeridirek. Skr., Ser. Havunders., **10**, 4, pp. 1—14, 1 fig. Bergen, 1952.

G. S. Saetersdal. "The Haddock in Norwegian Waters. 2. Methods in age and growth investigations." Fiskeridirek. Skr., Ser. Havunders., **10**, 9, pp. 1—46, 16 figs., 9 pl. Bergen, 1953.

In these two papers the author presents the first results of his investigations, started in 1948, into the biology of the haddock in the waters off northern Norway.

The first paper discusses the problem of stock segregation and identity in the area. This is approached by the analysis of regional variations in the three variables, vertebral number, brood fluctuations, and growth-rate. From the regional uniformity of these variables amongst young haddock and from the distribution of mature spawners and planktonic larvae, the author concludes that the northern Norwegian and Barents Sea area (north of latitude 64°N.) is inhabited by a single, widely distributed population of haddock with a main centre of spawning to the south of the Lofoten area, probably

to the south of latitude 65°N. The author leaves open the question of whether this uniformity extends to the south of the area sampled, but he draws attention to a single sample taken at about latitude 63°N., having a significantly lower mean vertebral number than those farther to the north.

The second paper deals first with investigations into the methods of age determination of the Norwegian haddock, and second, with the use of scales and otoliths in growth calculations.

A critical examination was made of scales and otoliths, taken from the same fish, in order to determine their relative merits for age determination. Scales were either bleached in peroxide and mounted in glycerine jelly, or celluloid impressions were taken, and they were then examined in a modified Edinger projection apparatus having an ×30 magnification. The otoliths, stored either dry or in 4 % neutralized formalin, were broken across the growth centre, and the broken surface was examined with a binocular microscope with a magnification of ×15—30 using a strong side-illumination. Age was determined by counting the number of opaque and hyaline zones in the otoliths, and the zones of broad and narrow sclerites in the scales.

The age readings in each case were compared with the results of applying Petersen's method of age determination to the length frequency distributions. This comparison revealed rather closer agreement between the otolith age assessment and the Petersen's method than did the scale assessment. The author attributed this to the absence of broad sclerite zones in the scales in some years. It is unfortunate that the analysis was made only on the younger age-groups, for which both scale and otolith assessment is relatively easy. The reviewer has found much greater discrepancies than are revealed here between scale and otolith age assessments of haddock older than 8—10 years.

From a study of the structure of the margin of the otoliths and scales taken from the "Brandisfjord" (latitude 64°N.) it was found that hyaline zone and narrow sclerites were the dominant marginal characters from October—November to May—June, and opaque zone and broad sclerites were dominant in the remainder of the year. The period of opaque zone and broad sclerite formation appeared to begin earlier and last longer in the south of the area than in the north.

The periodicity in zone formation was found to be closely related to the seasonal growth-rhythm. In a discussion of seasonal growth-rhythm on fish the author suggests that it is basically inherent, but that the inherent control may be modified by the influence of external factors such as temperature and abundance of food.

The first step in the investigation of the use of scales and otoliths in growth calculations for Norwegian haddock was to determine the form of the relationship between fish-length and some linear dimensions of scales and otoliths. Scales were taken from that part of the body — beneath the second dorsal fin in the median line — which gave the smallest variation in the computed lengths from one scale to another. Two measurements were made on each scale, its total anterior-posterior length, and the length from its centre to the posterior margin. The relationship between each of these measurements and fish-length was found to be linear between lengths of 16 and 60 cm. The eye-fitted regression lines through the two sets of points were found to have positive intercepts of 2 and 1 cm. respectively. The general formula for growth calculations is therefore given as:—

$$l = \frac{L-A}{S} s + A$$

where l = length of fish at intermediate age; L = total length of fish; S = total length of scale (either dimension); s = length of scale to intermediate age; A = intercept of regression line.

For the scale measurements taken from the centre to the posterior margin, which the author regards as preferable, the formula for growth calculations on Norwegian haddock becomes $l = \frac{L-1}{S} s + 1$.

A single measurement was made across the broken surface of each otolith, and the form of the relationship between it and fish-length was investigated in the same manner as for scales. These data did not give a single linear regression over the range of lengths investigated, but the relationship could be best described by two straight lines of different slope with the break occurring at a length of 20 cm. Because no simple formula could be deduced for this complicated relationship, graphical methods were used for estimating intermediate lengths from otolith measurements. It is evident, however, from Mr. Saetersdal's Figure 15, that a simple fish-length, otolith-length formula can be derived for fish greater than 20 cm., which can be used, in practice, for computing all intermediate lengths except l_1.

The l_1's calculated from scales agreed very well with the mean lengths of one-year-old fish samples in Brandisfjord. Values derived from otolith measurements were on average about 1 cm. higher than these values.

An interesting feature of the calculated l_1's, contained in Table 7 of the text, which were derived from fish between two to seven years of age, is the apparent absence of the well known "Lee's Phenomenon". It will be interesting to learn whether this is confirmed in subsequent analysis of larger samples.

In a concluding section the author shows that the relative number of the different year-classes in Brandisfjord remains constant during the first two years of life, and he concludes from this that there are no major immigrations or emigrations of these young age-groups from the time that they first enter the fjord in the autumn of their first year of life until at least their third year.

Both of these important papers are extremely well illustrated with text-figures and tables, and the second contains a valuable bibliography on the important subject of age determination and growth in fish. The author is to be congratulated on the clarity with which he presents his data, and on the completeness with which he pursues these important preliminaries to the long-term study of this little-known but commercially very important stock of fish. This is perhaps the most complete analysis which has been made of the relative merits of scales and otoliths for age and growth determination for a single stock of fish and it is undoubtedly an important contribution to the ever-growing volume of literature on this subject.

B. B. P.

R. van Cleve and A. H. Seymour. "The Production of Halibut Eggs on the Cape St. James Spawning Bank of the Coast of British Columbia 1935—1946." Rep. Internat. Fish. Comm., No. 19, pp. 1—44, 18 figs. Seattle, 1953.

The annual egg-production and the survival of the egg, larval and post-larval stages of fish remain problems about which a good deal is written but about which there are still all too little actual data. Therefore a paper such as this one is very much to be welcomed as contributing to fill the gaps. No doubt the difficulties involved in obtaining useful field data on this subject are a major cause of the paucity of such information.

The difficulty of obtaining estimates of the accuracy of determinations of annual egg-production necessitates the greatest care in planning the timing and carrying out of the observations. For this planning, adequate preliminary observations have to be made to establish the limits of the spawning in time and space. The paper under review tends to merge these two steps.

The authors state early in the paper that "The present report includes only the preliminary phases of an investigation covering the development of a simple and practical method of assessing the variations in numbers of eggs produced each year on one spawning bank" — the annual egg-production being required as an estimate of the stock of halibut in a particular area. The report does, however, set out the results of eleven years of halibut-egg surveys and proceeds to use the derived estimates of relative annual egg-production in a series of discussions and correlations, without establishing satisfactorily the reliability of these estimates. As the reliability of the results is fundamental to the conclusions eventually drawn, it is of interest to scrutinize the sampling methods used.

The fish-egg surveys and the contoured chart methods for working up the data which have been used here are established tools of fishery research; but the planning of the surveys is of first-rate importance and it seems that in this respect the present investigation is somewhat lacking. The errors of random sampling at any one station, which are discussed at some length, are surely among the least important sources of error; if the number of stations is adequate, the errors tend to balance out, as they are not directional. In this respect the observations for most years are probably adequate, though in 1942 the annual egg-production is based on only some 20 stations, of which at least half were on the edge of the egg-concentrations and gave corrected values of 1 or less.

By plotting the catches of eggs against the date on which the observations were made, for all years together, it is shown that 84 % of the younger eggs were caught between 30. December and 9. February. Only the observations between these dates were therefore used in the later calculations. It is also shown that the catches at the peak of egg-production were some $3^1/_2$ times as great as those at the beginning and end of the selected period. For the estimates of annual egg-production to be comparable *inter se* it is therefore necessary either for all the sampling to be made at the time of peak egg-production (which is probably impracticable) or for the sampling to be arranged in some way which adequately takes into account this build-up and die-away of egg abundance. However, it appears from Table 1 that in 1935 no observations were made during the central period between 9. January and 2. February, while in 1936 all the observations were made between these dates. Similarly in 1942 only 3 stations were worked between 6. and 27. January.

Another factor may also have considerable influence on the annual egg-production figures. The position of spawning is seen to differ considerably from year to year, although the locality of greatest spawning was usually not far from the southern end of the islands. If this implies that there is also a shift of the centre of spawning during each spawning season, as often occurs with fish, then the positions of stations and their timing require to be planned to take this shift into account. This question is not discussed, and as none of the raw data are given it is not possible for the reader to check such points for himself.

The method of working the nets allows for the water to be well sampled

at all depths, but there is no description of the method used to convert this catch to a catch below unit surface (essential where the contouring method is used). Also, where it is stated that the effect of temperature has been investigated and has been found to cause errors which are "insufficient to change the trends established from the original data", it is a pity that the reasoning is not set out, because the temperature data given suggest that the numbers of eggs present in the coldest winters were probably increased by at least 30 % or 40 % compared with the warmest of the winters, as a result of the longer time taken by the eggs to develop at lower temperatures.

From the summarized data that are presented it would appear that estimations of relative annual egg-production, of sufficient accuracy for their use as measures of the mature stock, would require annually a minimum of two complete surveys of the spawning area between the dates proposed and with approximately $2^1/_2$ weeks between the mid-dates of the surveys, thus ensuring that the period of maximum spawning was not missed.

A. C. Simpson.

P.-F. Meyer und **H. Kühl**. "Welche Milieu-Faktoren spielen beim Glasaal-aufstieg eine Rolle?". Arch. Fischereiwiss., **4**, S. 87—94, 1 Tafel, 3 Abb. Braunschweig, 1953.

The authors attempt to correlate the migration of elvers into a river with several different factors, viz., phase of moon, air temperature and pressure, salinity, water temperature, time of day, and tides. Daily records of elver catches from 1942 to 1953 at Herbrum, situated on the Ems, are used for this purpose, but very few of them are published, and no description is given of the precise manner in which they were employed. In 1952 direct observations were made.

Correlations are claimed to have been found only with the last two factors. It appears that elvers migrate only by night, and a strong association with the state of the tide is postulated. Elvers may be expected to appear only with the flood-tide at Herbrum and disappear the moment the tide turns. Catch data for two successive nights are published to support this view, but these may also indicate that the activity of elvers increases during the evening.

C. L. D.

G. Jens. "Über den lunaren Rhythmus der Blankaalwanderung." Arch. Fischereiwiss., **4**, S. 94—110, 1 Tafel, 11 Abb. Braunschweig, 1953.

In this excellent paper the records of the catches made by 5 fishing vessels over a period of 9 years are examined statistically, to study the migrations of silver eels in the river Rhine.

In the first place the author finds a correlation with water-level. Twice as many eels are caught when the level is rising as on a falling level. The possibility that this relation is caused by variations in the rate of water flow is not considered, however. It appears that a year with high mean level yields more silver eels than one with low mean level. But it is a pity that no account is paid to the levels in the different seasons, and the possibility is still open therefore that the differences in mean level mainly reflect differences in level during the season of migration.

With regard to phases of moon a beautiful lunar relation is demonstrated. The eels migrate mostly at about the time of the last quarter, and least at about that of the first quarter. The numbers migrating at the former time are

about 250 % of those migrating at the latter. The same phenomenon holds for the migration in the Baltic according to J e n s' s examination of data already published by M e y e r, although a notable difference between the two relations, not discussed in detail, is that the Rhine peak occurs before the last quarter and the Baltic peak after it.

To investigate the cause of the lunar relation, J e n s employs a graph of the catches made with clouded skies. Since this graph exhibits the same features the author concludes that light, i.e., moonlight, does not suppress the migration urge. In my opinion this conclusion may be wrong. When an eel has experienced throughout its whole life a lunar rhythm induced by moonlight, it is difficult to believe that the influence of such a rhythm is annihilated on a cloudy night.

Finally, the author presents a mathematical analysis of the lunar graph.

C. L. D.

W. S. Fairbridge. "A Population Study of the Tasmanian 'commercial' Scallop, *Notovola meridionalis* (Tate) (Lamellibranchiata, Pectinidae)". Austral. Journ. Mar. and Freshw. Res., **4**, 1, pp. 1—41, 8 figs., 1 pl., 8 tabs. Melbourne, 1953.

A draft paper on the "commercial" scallop was completed by W. S. F a i r b r i d g e shortly before his death in May 1950. The account was edited and presented by two of his colleagues. This interesting paper contains a comprehensive account of the Tasmanian scallop fishery and deals with the environment of the D'Entrecasteaux Channel, which is the present centre of the industry. In addition there are notes on the history of the fishery and methods of fishing, also a method of age determination, studies on populations, and notes on growth.

The history is dealt with in some detail, as are the methods of regulating the fishery. It appears that there was no real demand for scallops until after 1910 but that since that time there has been an increasing market for them. However, as the demand and fishing intensity increased, so the stocks and number of available beds decreased. Apart from overfishing, various tentative reasons are put forward to account for the virtual disappearance of scallops from areas such as the lower Derwent River but they are not substantiated. The main point is that the fishery has now become concentrated in the D'Entrecasteaux Channel and it is here that the main study was carried out.

Examination of data collected from 1922 onwards showed that there had been a large scallop population in the Channel and that the catch per dredge was high, at least until about 1941, but that since that time the catch had fallen until in 1950 and 1951 the average number of scallops per dredge was less than one-third of that in 1941. It seems reasonably certain that the decline in the numbers of "commercials" began at some time between 1941 and 1945, but analysis of returns was made difficult because two species of scallop are fished in Tasmania — the "doughboy" *Mimachlamys asperrimus* and the "commercial" *Notovola meridionalis*. No distinction was made between them in the earlier catch records. An interesting feature is that originally the doughboy was the more abundant and marketed in greater quantity. However, its numbers declined until it is now the commercial which is the most important species. The author mentions this change in population but there are no other details or suggestions of a possible cause.

Studies of water movements led to the supposition that there was little likelihood of loss of stocks due to dispersion of larvae, and also to the conclusion

that the Channel population was homogeneous. Apparently water flows into and out of the Channel at both ends and the water at the centre tends to be retained. It is likely that losses due to dispersion would be low but nevertheless the chances of loss must be increased if the larvae lead a prolonged planktonic life. Here the author laboured under the disadvantage that the larvae have not been described and the conclusions drawn were not, therefore, based on direct observation.

It is demonstrated that the well defined rings on the scallop shells are formed annually during a period of cessation of growth, which occurs during the winter from May to July. It is suggested that this cessation is not due to lack of food but to the fact that it is then that the gonad is developing most rapidly and there is consequently a great drain on the resources of the animal. Spawning has little effect, but the subsequent rapid growth may be related to the normal seasonal efflorescence of phytoplankton from September to November.

Using the annular rings, the author analysed the age and size composition of stocks and as a result showed that there had been little recruitment of juveniles into the population since 1941. The fishery has been dependent on good spawnings which occurred from 1939—1941. There are now few young scallops and there is no evidence to show either that they were missed with the sampling techniques used or that they migrated into the stock grounds at a later stage in their life history. The author was of the justifiable opinion that the present population was stable and in this case the idea of managing a fishery, which means balancing fishing and natural mortalities against growth and recruitment, became meaningless. He further suggested that the fishery might come to an end because with the dispersion of stocks the chances of fertilization were reduced and in addition any outbreak of disease would have a serious effect on the already depleted stocks. This does not seem reasonable because, as the stocks are so scattered, disease is less likely to be able to spread.

It is encouraging to note that the author's rather pessimistic forecast may not be true. There is a note that since he wrote the paper some beds of juvenile scallops had been found and though not large they do indicate that the Channel population is still capable of reproducing.

G. D. W.

C. Gilis. "La pêche crevettière sur la côte belge: son évolution au cours des années 1935—1951 et son influence sur le stock de la crevette." Inst. d'Etudes Marit., Mém. No. 8, pp. 1—55, 3 figs., 1 pl., 24 tables. Ostende, 1952.

The motive for Gilis's investigations was the decrease in the catch of shrimps, *Crangon vulgaris*, on the Belgian coast. During the period 1935—1939 the mean catch was 3·4 million kg. annually; during 1946—1951 it was only 1·7 million kg. This decrease cannot be explained by the reduction in the number of shrimp vessels. This reduction is entirely compensated for by an increase in the horse-power developed per vessel. Consequently the total horse-power of the whole fleet is about the same as in pre-war years.

That the stock of shrimps has diminished is shown by the catch per unit effort. In the period 1935—1939 the catch per one-hour fishing was 410 g. per HP; during 1946—1951 it was 294 g.

Gilis points out that adverse hydrographical conditions or the presence of particularly large quantities of predatory fish cannot be responsible for

this decline. He concludes that the intensity of fishing and especially the destruction of large numbers of immature shrimps must have caused the decrease in the stock.

Numerous experiments were carried out with the object of determining the influence of the size of mesh in the nets on the size of the shrimps caught.

In the experiments a series of comparisons was made between catches obtained with meshes differing by 2 mm., from the commercial mesh of 18 mm. to one of 26 mm. As in so many studies of the effect of mesh size, it proved that the total number of large individuals is greater with a large mesh than with a small. A mesh of 24 mm. yielded maximal catches, appreciably higher than those with a mesh of 18 mm. Increasing the mesh to 26 mm. reduces the catch, but 26 % more, in number, of immature shrimps are saved as compared with the 24 mm. mesh. Consequently Gilis is in favour of a minimum mesh of 26 mm. This would cause a small immediate reduction in the catches, but the catches would consist of larger shrimps, which fetch a higher price per kg. on the market.

These experiments are very valuable; they will form a solid foundation for all attempts to improve the stock of shrimps.

Gilis has also tried to assess the degree to which the presence of a large number of predatory fish has an unfavourable effect. He examined the stomach contents of the fish caught with the shrimps in the experimental hauls. The fishes found to prey on shrimps were *Raja clavata* (all the individuals caught, which were mostly small, contained shrimps exclusively), *Gadus luscus* (30 out of 34 containing food had eaten shrimps) and *Gadus merlangus* (50 out of 61 contained shrimps exclusively, and the other 9 contained shrimps with an admixture of other animals). As *G. merlangus* usually occurs in large numbers on the shrimp grounds, it may be expected to have a substantial influence on the stock of shrimps. Insignificant numbers of shrimps were found in the stomachs of *Limanda limanda*, *Pleuronectes platessa*, *P. flesus*, and *Solea solea*.

It was estimated that all the fish taken by the shrimp vessels, when newly caught, contained 200 million shrimps, i.e., 246,000 kg. The total consumption by these fish during the whole time they remained on the shrimp grounds cannot be ascertained, but it must be many times this quantity. It may therefore be assumed that in years when predators are very frequent, the mortality caused by them is as large, or even considerably larger, than the mortality caused by fishing.

B. Havinga.

G. A. Rounsefell and **W. H. Everhart**. "Fishery Science". Pp: xii, plus 444. John Wiley & Sons, Inc., New York. Chapman & Hall, Ltd., London. 1953.

The publication of a book designed by its authors "to present the problems that confront the (fisheries) administrator, the research worker and the student, and to show how to go about solving them" is an event in the history of fishery research. Indeed, this is the first book to be written with such an object in view, and the authors are to be congratulated on their objective. Other books will assuredly appear, but their publication will only enhance the significance of the first and emphasize the responsibility of the pioneers, whose task has been no small one.

Fisheries science is a border-line subject. More than a passing knowledge of several sciences is essential if the necessary wide view of fisheries problems

is to be taken, and to solve some of them quite detailed knowledge may be required — ranging from chemistry to statistics, with fisheries biology at the centre. The authors, aware of this, sensibly warn their readers, and to some extent disarm them, by offering "no apologies for omissions". This is reasonable, for omissions are inevitable. Nor must we be critical that this is not a text-book of, for example, aquatic biology: it was not meant to be. The weights to be given to different aspects of fishery science could provide interminable debate. Perhaps the only thing we can demand is that the principles be laid down clearly.

In their introduction, the authors draw attention to the familiar history of human irresponsibility, from deforestation to erosion, and from the careless release of sewage and industrial wastes to the excessive exploitation of marine animals. After a brief essay on experimental methods and sampling, they emphasize the fundamental significance of the life history of the organism in any attemt to "manage" it. Next comes a section on populations, and the factors which limit them, on distinguishing between different populations and the methods of estimating them, with some account of the snags to be anticipated. It is right that such a subject should be placed in the forefront of the argument, and many of the statistical methods demonstrated should be useful to the student.

Rather surprisingly, the next section concerns the construction, stocking, fertilization, and management of fish ponds. Then, after a review of different types of fishing gear, the protection of fish from hazards by the provision of fishways and screens is dealt with. This leads to the uses of screens for population sampling, and eradication of undesirable animals, after which the chief types of pollution are described and useful accounts are given of some methods of assessing their effects (but scarcely of resolving them, as seems to be implied on page 211). The insertion of the chapter on fishing gear may seem a little incongruous in this sequence (incidentally, the only reference in the book to an echo-meter is an unannotated photograph of an echo-chart at the beginning of this chapter).

A section on "improvement of habitat", defined as being for the sole purpose of providing better environmental conditions for desired species of fish, first reviews a fairly wide variety of fresh waters, and then includes some very necessary notes on measuring the effects of "improvements" with examples of the frequent mistakes which have been made in the past. This is followed by a chapter on the control of undesirable freshwater species.

Another abrupt change of thought introduces a section on fish tagging and its uses. As one would expect from the senior author, the review is an interesting and important one. Yet, even though tagging has produced some information of use in age determination, it is a little disconcerting to be reminded (p. 297) that age and growth have not yet been discussed and are consequently the next subjects on the list, only to be followed in succession by "collecting basic data", "managing natural populations", and "problems" (in the last 7 to 8 pages).

It is no criticism to say that no other workers would have spread their emphasis in just the same way as R o u n s e f e l l and E v e r h a r t. Probably no European fisheries worker, either in the marine or freshwater field, would have given anything like the same emphasis. It is indeed stimulating to realize how different may be the point of view taken, and this book may give a number of Europeans a better idea of the significance of freshwater fisheries for the North American. For all that, the North American yield from its marine fisheries is by no means modest, when compared with that

of Europe, and it is very much greater than its freshwater yield. Even after weighting these ratios by a reasonable factor for sport interests (and there appears to be more emphasis on sport fish than commercial freshwater fish, as the only coloured plate, on fresh water salmonids, shows), one must wonder whether the marine side has not been relatively neglected. This is not to deny the authors full right to arrange their emphasis wholly on freshwater fish if they wish, but any tendency to do this lessens the justice of the title "Fishery Science". The foreword (by the Assistant Director of the Fish and Wildlife Service) makes a point of the authors' intention to cover both, and they rather more than imply that this was their aim.

A rather surprising statement on page 46 seems significant, "Total productivity applies to the sea as well as to the freshwaters"! Not only does one get the impression most of the time that the fresh waters provide the dominant interest, but considered assessment reinforces the conclusion. A simple test is that of references — so important to the scientist and student alike, and not irrelevant to the administrator. We find about twice as many freshwater references as marine. It cannot escape notice, too, that there are well over five times as many North American references as European, and this may seem excessive, even though the book may be chiefly designed for use in the North American Colleges and Universities.

To some extent, the two biases are inter-related. Although it may not be true of European freshwater research in general, it is probable that far less attention has been paid to freshwater fisheries research in Europe than in North America — and certainly much less must have been spent on it. The same cannot be said or implied so justly, however, of European marine fishery research, and the comparatively few references to this scarcely do justice either to the pioneers, three of whom the authors acknowledge in their preface, or to their fairly numerous followers. Nor does this only concern due acknowledgement. In the section on back-calculation of length from scales, as one among several examples, nothing has been gained, and something useful lost, by the omission of L e a' s work on the problem.

Again, the chapter "Effects of Exploitation", of four-and-a-quarter pages (including a picture of a New England trawler), scarcely does justice to a major danger, even though there are other references to exploitation. The chapter has only three items in its bibliography, two of which are not mentioned in the text. This can scarcely be expected to focus the attention of either the student or the administrator on the more urgent problems, and the principles which should guide any approach to them.

Perhaps it is here that the reviewer can legitimately take issue with the authors. Despite the refreshingly critical attitude which they have adopted to some of the earlier attempts to "solve" fisheries problems, there is nowhere a clear statement of the factors on which the balance or disturbance of a fishery depend. Neither "overfishing" nor "underfishing" are adequately reviewed. Nowhere is one informed that there have been several useful attempts to formulate the "fishing equation" in comprehensible and dynamic terms; neither is there an adequate discussion of the effects upon the stocks of various rates of fishing nor of environmental trends. Finally, there is no clear demonstration of the prime need to allow the smaller fish to live long enough (but not too long) to reach their optimum size for economic fishing. The occasional hints given in the freshwater field at best provide poor guidance for the larger issues met in sea fisheries, and they prepare no one, least of all the administrator, for the international complexities which are so inevitable.

It is a pity that the International Commission for the North-West Atlantic Fisheries, so ably brought into being by the United States Government in 1949, and its first attempt at fisheries legislation, should not be mentioned. Nor is there a discussion of the similarities and differences between depletion in the Pacific halibut stocks and, for example, in the plaice and haddock stocks of the North Sea. Yet they could have provided opportunity to illustrate several valuable points, not least the solution adopted for the one, and that proposed and about to be adopted for the other. Each of these three problems concerns a valuable fishery, and the measures taken to deal with, or to anticipate, an international danger. Unlike the administrators, perhaps few fishery students and scientists will personally have to deal directly with such matters, although their work will more and more affect the decisions taken by the administrators. It is essential that the scientists should be influenced as little as possible in their research by such worries. It is important, however, that they should, at all times, be guided by sound bionomic principles and acquire an understanding of the responsibilities demanded by such far-reaching problems. The responsibilities, both social and scientific, of the fisheries scientists press a little more immediately on him than is the case in some research fields.

C. E. L.

Current Bibliography.

Prepared by the Editor with the Assistance of Mr. A. R. Margetts.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given. but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only. for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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